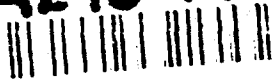AD-A248 769

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GRADUATE STUDENT RESEARCH PROGRAM
(GSRP) REPORTS

VOLUME 6

ARMSTRONG LABORATORY
WILFORD HALL MEDICAL CENTER

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RESEARCH & DEVELOPMENT LABORATORIES

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GRADUATE STUDENT RESEARCH PROGRAM (GSRP) REPORTS

VOLUME 6

ARMSTRONG LABORATORY
WILFORD HALL MEDICAL CENTER

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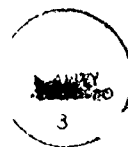Program Administrator, RDL
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PREFACE

Reports in this document are numbered consecutively beginning with number 1. Each report is paginated with the report number followed by consecutive page numbers, e.g., 1-1, 1-2, 1-3; 2-1, 2-2, 2-3.

This document is one of a set of 13 volumes describing the 1991 AFOSR Summer Research Program. The following volumes comprise the set:

VOLUME	TITLE
1	Program Management Report

Summer Faculty Research Program (SFRP) Reports

2	Armstrong Laboratory, Wilford Hall Medical Center
3	Phillips Laboratory, Civil Engineering Laboratory
4	Rome Laboratory, Arnold Engineering Development Center, Frank J. Seiler Research Laboratory
5	Wright Laboratory

Graduate Student Research Program (GSRP) Reports

6	Armstrong Laboratory, Wilford Hall Medical Center
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High School Apprenticeship Program (HSAP) Reports

10	Armstrong Laboratory
11	Phillips Laboratory, Civil Engineering Laboratory
12	Rome Laboratory, Arnold Engineering Development Center
13	Wright Laboratory

1991 GRADUATE STUDENT RESEARCH REPORTS

Armstrong Laboratory, Wilford Hall Medical Center

Report Number	Report Title	Author

Armstrong Laboratory

Armstrong Aerospace Medical Research Laboratory (AAMRL)

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2	Simulation of Head/neck Response to +Gz Impact Acceleration due to Additional Head Mass	Christina Estep
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7	Animal Testing in Combustion Toxicology of Halon Replacement Agents	Vincent Stone
8	Not Available at this Time	Cortney Vargo

Human Resources Laboratory: Logistics & Human Factors Division (LHFD)

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10	Modeling Composite Wings: An Object Oriented Simulation Approach Using MODSIM II	Jaqueline Schnepp

Human Resources Laboratory: Manpower and Personnel Division (MPD)

11	Individual Differences (Impulsivity) and Personnel Selection	Denise Brady
12	Prototyping GAIDA: A Learning and Developmental Process	Steven Hancock
13	The Leadership Effectiveness Assessment Profile (LEAP) Summer Research Activities	Amie Hedley-Goode
14	The Relationship Between Working Memory Capacity and Context Effects in Lexical Access	David Hess

STUDY AND DESIGN OF A THREAT AND ASSOCIATED EMITTER PARAMETER DATABASE FOR THE B1-B ENGINEERING RESEARCH SIMULATOR AND ADVANCED DEFENSIVE MISSION PLANNING SYSTEM.

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ABSTRACT

The aim of this research is to create a realistic and accurate simulation of a ground site threat, store this in a emitter database, and then incorporate this data into the Advanced Defensive Mission Planning System (ADMPS). Close modeling of the electronic emissions and geographic laydown are essential for worthwhile electronic countermeasure crew simulator training. The ADMPS program and B1-B Engineering Research Simulator (ERS) at Armstrong Aerospace Medical Laboratory is the focal point of this study. A key goal is to create a ground threat simulation with methods that are compatible with other defensive system simulations. Emphasis is placed on crew training and EWO mission standards, so a high level of accuracy and realism is demanded of the hardware and software.

I. Introduction

Extensive research is conducted at the Armstrong Aerospace Medical Laboratory in strategic aircraft defensive systems. The survivability of manned strategic weapon systems in today's theater of operation demand a high level of crewmember training, electronic countermeasure equipment, and evolving tactics. The purpose of ADMPS is to provide a mission planning system that can create a mission site threat laydown that emulates the theater threats, is easily revised, and does not require a expert mission planner for generation. Currently, a mission laydown is accomplished manually by a expert in threat characteristics and tactical/strategic deployment.

II. Discussion of the problem

ADMPS must meet threat data accuracy standards, support a non-expert user, have a exportable database, and produce a realistic mission laydown. The programming format should be compatible with other simulators so that it can be exported to other systems. Current threat site laydowns are done manually and are based on a experts knowledge and personal experience. Improved standards can be developed in ADMPS to provide more realistic crewmember training.

III. Design Considerations

This summers research began with analysis of the ADMPS tasks that lead to several major functions and four major software categories.

A. Command Level Considerations

The command structure of each and every threat is a key factor in its operational deployment. Communication networks link each site and can dictate the site laydown. I researched the command structures of several surface to air missile sites and computed the relative bearing and range of each in reference to a common point. This modeling resulted in several tactical laydown options for each site.

B: Threat Considerations

The modeling of a surface to air missile site, airborne interceptor, and other emitters require a database that contains a library of data parameters. The command and control parameters dictate the operational range, geographic positioning and actual existence of specific emitters. The type of site also dictates what scan modes to expect and the broadcast timing. Electronic emissions can be found in several forms ranging from pulses, surges, spikes, tones, or a combination of all four. I've mentioned only a few of the many categories that will reside in the database. These parameters change periodically and require updating for accurate threat emulation.

C: Mission Considerations

Aircraft type and mission profile are keys to laydown design. Timing, altitude, airspeed, and electronic defensive capabilities dictate the magnitude of the threat and its received signature. Strategic aircraft flying outside the effective kill range of a missile site will still receive emissions and must then decide whether a defensive maneuver or action is necessary. In order for this to be accurately modeled, all potential emitters should be included and represented in the Mission laydown database.

D: Site Considerations

Geography and Command Structure directly impact the emission signature that is broadcast. Soviet military

tactics include several options that pertain to actual site deployments. This complicates the modeling task and adds considerable incentive for flexible database design. Adding to the complexity of the database are emitter sector coverage, radiating power, and ground clutter.

COMMENTS AND RECOMMENDATIONS:

1. The ADMPS software design will be a key determiner in the transportability of the system to other simulators. I recommend this compatibility because it will help justify the expense and standardize crew training. This assumes that the complete threat database is resident in ADMPS.

2. At the very least, update and revise the Engineering Research Simulator (ERS) database to allow for future incorporation into ADMPS.

**1991 USAF-RDL SUMMER FACULTY RESEARCH PROGRAM/
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<u>**FINAL REPORT**</u>

<u>**Simulation of Head/Neck Response to +Gz Impact Acceleration due
to Additional Head Mass**</u>

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USAF Researcher:	Ints Kaleps, Ph.D.
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Simulation of Head/Neck Response to +Gz Impact Acceleration due to Additional Head Mass

by

Amit Lal Patra (Summer Faculty Research Fellow)

University of Puerto Rico at Mayaguez

Christina Estep (Graduate Student Research Fellow)

Virginia Polytechnic and State University

ABSTRACT

This work was to extend research initiated at the Armstrong Laboratory (AL) to investigate the effects of added head mass on the dynamics of the neck and head during +Gz impact acceleration. The original effort was conducted to provide an analytical modeling foundation for a better understanding of the dynamic response of the head/neck system when encumbered with additional masses such as helmet, night vision goggles, mask or other performance enhancing or protective equipment. The summer effort include a literature search and the validating of a modelling methodology for +Gz impact response. The emphasis was on modelling experimental data obtained from tests on human volunteers for head acceleration and neck flexion. The work predicted loading at the occipital condyle interface, and performed extensive model parametric studies to explore the changes in acceleration, flexion and neck loading due to variations in the amount and placement of mass on the head.

ACKNOWLEDGEMENTS

INTRODUCTION:

The concern about the problem of neck injury during ejection was addressed by an 1984 AGARD working group. Their findings showed that non-ejection high manoeuvering loads resulted in cervical fractures more frequently than ejection situations. The introduction of night vision goggles, helmet mounted sighting and display systems in advanced military aircraft environments can be expected to exacerbate the injury risk to aircrew and perhaps increase the likelihood of cervical injury. Unfortunately there exist limited useful data in the published literature to provide guidelines for allowable added mass on the head.

Computer models in the published literature primarily deal with occipital condyle (C1-C2 region) shear and torque forces due to flexion and extension of the head/neck systems. There exist considerable data on the response of the human neck to -Gx impact acceleration. These data were accumulated from human volunteer studies, cadavers and computer simulations. Mechanical dummies were also used to compile data for higher acceleration exposure levels. Unfortunately, the data on the response of human head/neck due to +Gz acceleration are limited and almost non-existent for situations with head mass.

This summer AL/CFBV conducted a review of the existing data for +Gz acceleration exposures in the published literature to provide an overview of the present biodynamical knowledge. With the aim of

developing limits on allowable added headmass, the effects of added mass and its location on the head were evaluated. Computer simulation, parameter selection and validation with the experimental data collected at AL were attempted. The specific aspects of human neck response investigated included human and analog +Gz accelerations response; injury mechanisms; tolerance levels; measurements and/or calculation of forces in the head/neck joints; effects of added mass on the head due to helmet and/or helmet mounted devices; and modelling of impact acceleration and vibrational effects.

OBJECTIVES & LITERATURE REVIEW:

The scope of our summer research effort was to identify pertinent information available or lack of it relating to head/neck response due to +Gz impact acceleration in the literature. Some forty publications in this field were reviewed, list of which is appended in the reference section. These papers were grouped according to their major subject areas. Publications focusing on epidemiological relationships, experimental investigations, review of current knowledge of the subject materials, added mass criterion on the impact situation, computer simulations etc., were reviewed.

Number of papers overviewed historical knowledge relating neck injuries, kinematics, clinical biomechanics, use of electromyography for muscular loading phenomenon in head/neck

response. Guill and Herd (2) analyzed ejection related neck injuries for the 1949-1988 period, and suggested caution relating integration of systems into aircrew helmets. Clark (3) investigated positive effects of botulinum toxin in cervical muscles dystonia. Shanahan and Shanahan (10) reviewed kinematics of US Army Helicopter Crashes during 1979-85. They compared their data with existing design standards and suggested standards be modified, based not only on horizontal velocity but also in roll, to crashworthiness of helicopters. Phillips and Petrofsky (31,32) used volunteer electromyography to investigate neck musculature signals due to helmet loading. They showed definite effects of cg off-sets and addition of extra mass on head. But Tennyson et al. (22) showed, using electromyographic signals, that there may not be enough time for the muscle forces to provide effective restraint in case of a high g exposure. Coffee et al. (33) and Panjabi et al. (27) investigated in vitro loading to failure of human cervical spines. The differences in the data obtained varied widely. The compressive and tensile stiffness on an average were much larger (1435 and 224 N/mm) in (33) when compared to (140 and 53 N/mm) in (27) respectively. The difference can be attributed to the two different techniques used for experiments; in (27) the cervical spine were severed as the experiment progressed but in (33) the spine were kept intact.

Brinkley (13) reviewed operational efficacy of USAF flight helmets used during 1963-1967; suggesting better shoulder harness and presence of helmet were major factors for head injury

prevention. Sandstedt (11) reviewed all cases of ejections in the Swedish Air Force during 1967-1987. His findings show that even with a heavy helmet the percentage of survivable ejections was excellent, even though a high velocity ejection were common among the reported cases. A design with lower DRI also helped with the improvement in survivability. Over 90% of the ejected pilots returned to active duty of flying.

Procedures to determine the cg and moment of inertia of the human head and neck were presented and a standard for co-ordinate systems was defined by Becker (17). An approach to modelling human head/neck response to -Gx impact accelerations was attempted by Becker(16). Walker et al. (25) reported mass, volume, center of mass and mass moment of inertia of head and head/neck joints for human cadavers. Findings were similar to those presented by Becker(17). But Ewing and Thomas (26) study was first to report systematic standards of anatomic parameters used in impact studies.

Foust and his co-workers (19, 20, 21) presented a series of neck muscles response data for cervical motion due to car crash situations. Human volunteer response and simulation modeling suggested dependence of reaction time to mitigate forces effected on a collision; major findings were, higher age would lower the muscle strength, and muscle response were strongly related to sex.

Effects of whiplash on cervical spine due to head accelerations were documented by McKenzie and Williams (35), Mertz and Patrick (34) and Ewing and Thomas (26). A discrete parameter model of head, neck and torso were used by McKenzie and Williams to predict kinetic forces within established published experimental methods (35). Kinematics of whiplash, based on an actual car crash acceleration pulse, were reproduced using a volunteer, cadavers, and dummies (34). Ewing and Thomas (26) compared human test data with those of Mertz and Patrick (34). The standardized methods of collecting dynamic response parameters in this -Gx study, suggest methods for analyzing future dynamic responses in other impact directions (i.e., +Gz).

Settecerri et al. (36) used a Hybrid-III dummy to evaluate inertial loading effects due to head encumbering devices. Their study, although no cg shift effects were considered, supported the theory that added mass on the head would increase severity of loading on the cervical spine.

Verona and his co-workers (8, 9) compared the two types of imaging techniques based on two different optical principles, image intensification and thermal imaging, being used for night vision goggles in army helicopters. The excess weight (5.3 lbs) due to NVGs was analyzed on the basis of human factors and safety considerations. Majority of accidents (28 out of 37) reported were sensor and/or display system related. Analysis of night vision goggles for military helmet mounts presently being used were

reported in a series of articles (28, 29, 30). Comparisons between AN/PVS-5 and ANVIS showed reduction of added head mass (from 680 gm to 463 gm) and lower eye relief (from 21.6 mm to 16 mm) for ANVIS system.

Thurston and Fay (39) built a mechanical model of the head/neck to simulate neck motion due to impact acceleration. A non-linear harding spring was used for the simulation model. Mertz et al. (12), using a Hybrid-III dummy head, tested different football helmets. They reported that the position of the torso at the time of impact would affect the bending moment at the neck joint. Verona et al. (9) cited Glaister (15) for an upper value of added mass on the head as 4.4 lbs (2.0 kg). Glaister's concern was with respect to head injury and protection based on penetration resistance, shock absorption, rotational acceleration, but did not specify why 2.0 kg added mass should be the ideal weight.

Mertz and Patrick (34) attempted to develop an index for severity of impact using human static tolerance limits as a basis. Mertz et al. (12) also developed an injury reference curve based on qualitative observations from dummy tests. From historical data Glaister (15) studied tolerance of human the head to direct impact acceleration. The linear G-value for tolerance for head injury was reported to be 300-400 Gs. Darrah and co-workers (4-7) developed a computer model of head/neck simulation for +Gz acceleration incorporating asymmetrical loading. Using human centrifuge experimental data, the model was validated. They simulated three

head loads and five offsets from the atlas. The results predicted maximum tolerance of +3.5 Gz with any added weight. The model with NVG resulted in increased applied neck torque to 267.7 in-lbs. The human volunteer study showed possible head motion at +6.0 Gz unloaded and +5.5 Gz with any kind of loading. The fatigue tolerance curve simulated by Darrah and co-workers (4) was obtained as a function of seat back angle, +Gz load and duration of stress. Their physiological limits were set by the cardiopulmonary system limits.

Using the ATB model, Freivalds and McCauly (1) simulated helmet assembly mass and center of gravity effects during ejection. Among the variables looked into were head acceleration, torque and flexion angle which were assumed to be of importance and were shown to be significantly correlated to CG offsets. The relationship of ejection seat back angles with head rotation was significant too. Raddin and his co-workers (41) using the concept of relative velocity suggested a neck protection system for aircrew in high performance aircraft.

Using a 10 G pulse in both -Gx and +Gz directions and 3 lbs helmeted weight, King et al. (24) simulated head and neck response. It was shown that simultaneous impacts of both -x and +z directional accelerations increase neck shear and moment, head acceleration, head displacement, and neck muscle forces. Privitzer and co-workers (37, 38) made analysis of dynamic inertial loading of head mounted systems due to +Gz acceleration on the head/neck

system. They imp`emented a spinal injury function and baseline response criteria using a three dimensional head-spine model for head mounted devices.

Mertz and Patrick (14) performed a static and dynamic response study of neck strength on volunteers and cadavers. Non-injurious tolerance values for hyperextension and flexion of neck for different G values were plotted using equivalent moments and head position as parameters. A response envelope was drawn. Tolerance levels for the neck in flexion and extension were developed using physiological responses from the volunteers and from x-ray views of the damage at the cadaver neck. Injuries applicable from animal studies were suggested by Ewing (23) for extrapolating to human neck. Ewing developed an envelope using a comparative model between man and human analog (primates) to validate the analytical human head/neck response.

VonGierke (18) and Anton (40) made overviews to discuss recent advances in +Gz acceleration impacts. Topics focused included, application of ATB model in ejection simulation, body deformation under ejection forces simulated with HSM, neck muscle responses by King et al.(24), development of injury criteria, and analysis of epidemiological data compared with simulations. Their findings emphasized the accumulated knowledge but also highlighted the short comings of our data base.

DISCUSSION:

Most of the information available for impact acceleration are for -Gx. There exist little data either for the Y or the Z direction. The Y-directional motion is minor and thus can be neglected for detailed study. Z-directional motion on the contrary is of significant importance to Air Force due to pilot ejection concerns. The lack of existing pertinent data indicated that the Air Force should undertake a human volunteer study and develop a simulation methodology to predict injury likelihood due to added head loading during ejection.

Following the human volunteer protocol developed by Ewing et al. (26) for -Gx acceleration a method to study human head/neck response in the +Gz direction has been developed by AL. Among the data recorded are head and chest accelerations. The photographic records are also analyzed to determine the kinematics of the head, shoulder, and neck. The Articulated Total Body (ATB) model has been used to simulate the head and neck response for +Gz impact using the experimentally obtained chest acceleration as input.

The simulation uses certain specific parameters, i. e., neck stiffness, damping force etc. as inputs for validation with the experimental results are not clearly defined. The added head weight of 6.8 lbs due to fielded night vision goggles (e.g., AN/PVS-5) should be recommended as an upper limit in the simulation (8,9). The maximum off-set of head load placement was presented by

Glaister (5) as 152 mm forward of the atlas in the only human volunteer experiments for +Gz acceleration reported. The maximum +Gz sled acceleration experienced by the volunteers was 6.0. The combination of added head mass and +Gz acceleration would be controlled by the maximum safe neck torque. A value of 267.7 in-lbs was used by Darrah et al. (6). The neck torque of 270 in-lbs could be used as a limit for experimentation. This value is about half of Mertz and Patrick (14) x-directional volunteer data for 8.0 G sled acceleration. An angular acceleration of 50 rad/sec was used by Ewing (23) equivalent for concussion in humans. This could be used as an upper limit of the simulation. Mertz and Patrick (14) suggested an envelop using the initial slope of the volunteer response of neck strength as 3 ft-lbs/degrees. This was based on -Gx sled acceleration, but since no similar data is available , this can be used as a guide for +Gz sled acceleration also. The neck muscle force response can be neglected in the simulation, at least at the beginning, as reaction time is generally longer than the ejection critical acceleration exposure time (19-22, 31-32). The loadings on the cervical spine were reported as 18 N-m (33),and 57 N-m (14) bending moment, the tensile stiffness was 224 N/mm (33), and 53 N/mm (27), and the compressive stiffness was 1435 N/mm (330 and 140 N/mm (27), providing a wide choice for the working range. The simulation should be validated from within these values.

The development of a tolerance envelope would constitute some problem. In the x-direction, where there are enough data available, the envelope suggested by Mertz and Patrick (14) is at

best questionable. In the +Gz direction, data are limited. The computer simulation and predictions made by different investigators (1, 7, 24, 34) were mostly not validated by experimentation. The little data that are available suggests limited range of operation. The historical data analyzed by Sandstedt (11), on the contrary, suggests that most ejections with proper helmets are survivable with over half of the ejections causing minimal injury to the pilots.

The major findings of some of the papers underline some key results. Hertz and Patrick (34) for the first time suggested a injury envelope based on their cadavers and volunteers studies. Darrah and his co-workers (4-7) attempted computer simulations and experimental validation of added head mass due to helmets and helmet mounted devices. They documented effects of cg offsets and their contributions to cervical stress and strain due to head loading. Sandstedt (11) in his research investigated survivability from actual ejections and suggested 100% survival rate with proper head protection. All the reported cases of the pilots ejected made return to active duty status, although the loading on the neck due to the heavy helmets used in the actual ejection was high. Privitzer and Kaleps (38) developed a three dimensional computer model of head and spine that could successfully predict kinematics of the spine. The opens the door to further developments of other body parts motion in a similar manner.

RECOMMENDATIONS:

A mathematical model of human motion provides an inexpensive source of database for impact acceleration assessments for crash situations. The scope of the project allowed only simulations using one directional acceleration data to be completely investigated. Therefore, the simulation is recommended for use in predicting qualitative motions of the head acceleration and head pitch under added load conditions. In using the ATB model for predicting loading at the occipital condyle interface due to additional Head Mounted Devices (HMDs) it is recommended that a study of torque characteristics of the head and neck joints first be conducted and included in the program.

Once a methodology for using the ATB model for +Gz impact is complete, extensive model parametric studies could be performed to explore the changes in acceleration, flexion and neck loading due to various amounts and placements of mass on the head. An injury tolerance limit envelope and severity index criterion for ejection should then be attempted, using the validated simulation model.

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COMPARING THE EFFECTS OF CHARACTER SIZE AND DIAL
SEPARATION ON RAPCOM AND SPATIAL DISPLAYS

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COMPARING THE EFFECTS OF CHARACTER SIZE AND DIAL SEPARATION ON RAPCOM AND SPATIAL DISPLAYS

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ABSTRACT

Matin and Boff (1988) have shown that RAPCOM display formatting can potentially increase performance in human-computer interactions involving high information transfer rates. More recently, an attempt by Uhlarik and Renfro (1990) to confirm these results has produced somewhat conflicting results. It was hypothesized that these differences were primarily a result of the different character sizes and degree of spatial separation between dials in the two respective experiments. The present study was conducted to investigate these differences. Performance was measured in terms of latency to response and accuracy. Results indicated performance differences resulted from differences in character size and spatial separation. RAPCOM displays produced more accurate performance overall. However, the use of minimally-separated digital dials with large characters produced the most accurate performance. It is recommended that designers consider these results when evaluating performance for these displays.

INTRODUCTION

The use of computer-driven instrumentation to display visual information has provided many opportunities for improving information display technology. For example, the use of such instrumentation has increased both the amount and speed of information display. Unfortunately, these improvements are not without cost. Presenting more information faster usually causes an increase in mental workload (Tole, Stevens, Harris and Ephrath, 1982). Problems arise wherein the user is unable to process increased amounts of information at faster presentation rates.

The effective implementation of new display technology requires research into display formats which overcome problems such as increased mental workload. For instance, the head-up display attempts to reduce pilot workload by eliminating the head and eye movements typically associated with scanning a multitude of cockpit displays. In practice, designers should explore formats which will both take advantage of computer automation and also be compatible with optimal human information processing capabilities.

Recently, Matin and Boff (1988) have introduced RAPCOM (for RAPid COMmunication display), a display format which presents independent frames of information in temporal succession at a single spatial location. In addition to reducing physical display space requirements, RAPCOM provides for optimal information sequencing and is said to increase the rate of machine-to-human information transfer (Matin and Boff, 1988). Matin and Boff (1988) and their

colleagues (Swierenga, Boff and Donovan, 1988; Swierenga and Donovan, 1990) have used a number of tasks to illustrate RAPCOM's ability to increase information transfer beyond the levels of a conventional spatial display.

In a series of experiments which used an echo and a monitoring task, Uhlarik and Renfro (1990) compared the RAPCOM display with a spatial display and failed to confirm the results of Matin and Boff (1988). Using three dials with larger characters and a smaller spatial separation between dials, they found the spatial display produced lower duration thresholds and more accurate performance. These findings pose questions about the ability of the RAPCOM display to enhance the rate of information transfer and therefore suggest its utility may be limited.

The purpose of the present experiment was to compare the original display conditions of the Matin and Boff (1988) experiment with those used by Uhlarik and Renfro (1990). It was hypothesized that the conflicting results of the previous studies could be attributed to both variations in character size and the overall separation of the dials in the spatial display.

METHOD

Seven subjects participated in the study. Twelve different displays were created by factorially combining three variables: display mode (RAPCOM, 0 deg; small spatial, 6.3 deg; large spatial, 12.0 deg), character size (.45 deg, .60 deg), and dial type (digital, analog). The conditions were randomly presented within each of four frame durations (170, 221, 272, and 323 ms). Pilot studies

indicated this was an optimal range for the control of floor and ceiling effects. A chin rest fixed the viewing distance at 64 cm from the computer screen.

Data was collected over three days, with each daily session consisting of 320 trials. A single trial consisted of the presentation of three dials and the subject entering correct dial values, in a prespecified order, using a numeric keypad. Total presentation time for each trial was calculated by multiplying a given frame duration by the number of dials displayed. Thus, a RAPCOM presentation of three dials for 170 ms each was equivalent to the total presentation time of a spatial display, or the simultaneous presentation of three dials for 510 ms.

RESULTS/DISCUSSION

Separate repeated measures ANOVAs were used to analyze the two dependent measures: percent correct and reaction time. Only correct responses were included in the analyses. Frame duration had only systematic effects on performance and, as a result, was excluded from further analyses. As expected, longer durations produced quicker and more accurate performance, $F(3,18)=11.54$, $p<.0002$. There were no effects of replication over the three experimental sessions.

Analysis of reaction times produced an effect for dial type, $F(1,6)=18.21$, $p<.0053$. Given that the task was to indicate an absolute value displayed on a dial, it is not surprising that digital dials were processed significantly faster ($M=736$ ms) than analog dials ($M=994$ ms). The effect of display mode was

insignificant, suggesting presentation using a RAPCOM display did not speed information transfer rates.

All analyses of accuracy scores were significant. Figures 1 and 2

Insert figures 1 and 2 about here

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illustrate the effects of display mode and character size on accuracy for analog and digital dials, respectively. Accuracy was significantly higher for RAPCOM displays, $F(2,12)=37.61$, $p<.0001$. However, the presence of a three-way interaction between character size, dial type and display mode suggests this effect was not systematic, $F(2,12)=32.51$, $p<.0001$. Close examination of Figures 1 and 2 reveals that for the spatial displays, character size and dial type affected accuracy differently. Thus, specific comparisons were conducted to examine these differences.

Overall, large characters were associated with greater accuracy ($M=76.37\%$), relative to small characters ($M=60.77\%$), $F(1,6)=230.69$, $p<.0001$. Though the effect of character size on accuracy was manifested in the two spatial displays, Figures 1 and 2 indicate the effect was more pronounced in the smaller spatial display. When large characters were used in this display, performance was significantly more accurate, $F(5,30)=45.69$, $p<.0001$. In fact, this condition equalled accuracy performance for RAPCOM conditions.

Analog dials ($M=75.83\%$) were processed significantly more accurately

than digital dials (M=61.31%), $F(1,6)$=50.73, $p<.0004$. As spatial separation of the three dials increased, accuracy for digital dials decreased significantly more than that for analog dials, $F(5, 30)$=33.06, $p<.0001$. When digital dials were used in small spatial displays, accuracy performance was equivalent to that of the RAPCOM conditions.

Finally, and perhaps most interesting, the small spatial display which used digital dials with large characters was significantly more accurate than any of the RAPCOM displays, $F(4,24)$=8.84, $p<.0001$. In fact, this display fared nearly 10% better than the most accurate RAPCOM display.

CONCLUSION

Recall that, overall, RAPCOM displays produced more accurate performance with no significant speed advantages. However, as figures 1 and 2 illustrate, performance for spatial displays was affected by a number of factors. The findings of Matin and Boff (1988) and those of Uhlarik and Renfro (1990) are indicative of the influence of these factors. To test RAPCOM, the former study used a spatial display comparable to that which yielded the worst performance in the present study, while the latter utilized a display comparable to that which produced the best performance.

The present study provides a framework for the evaluation of RAPCOM. Toward this end, it has provided the conditions under which RAPCOM enjoys performance advantages. The results reported here suggest that, under certain conditions, character size and spatial separation interact to affect performance.

Thus, any performance evaluation of similar display formats should control for the effects of these two variables.

ACKNOWLEDGMENTS

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FIGURE CAPTIONS

<u>Figure 1</u>: Mean percent correct by display mode and character size for analog

dials.

<u>Figure 2</u>: Mean percent correct by display mode and character size for digital

dials.

FIGURE 1
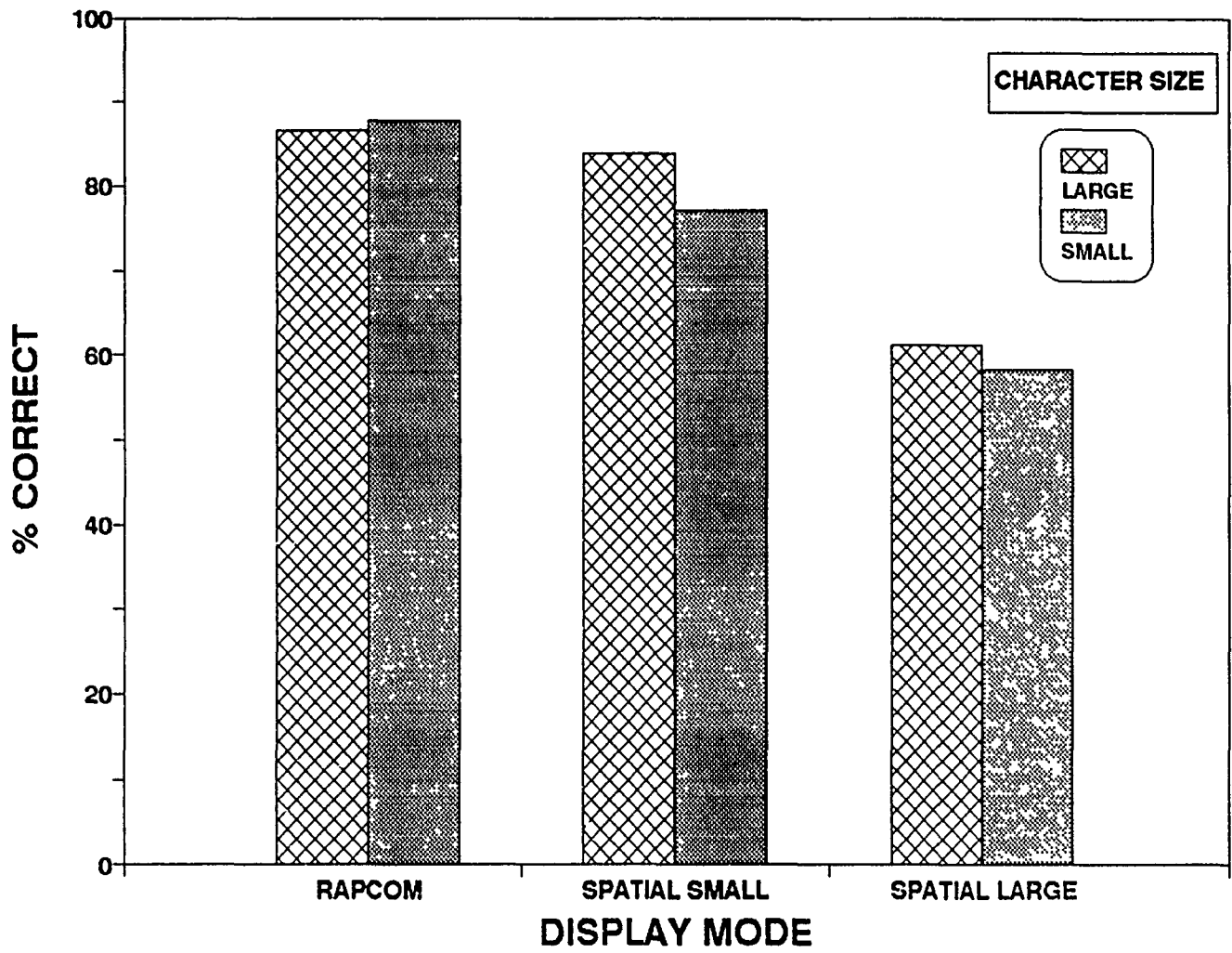
FIGURE 2
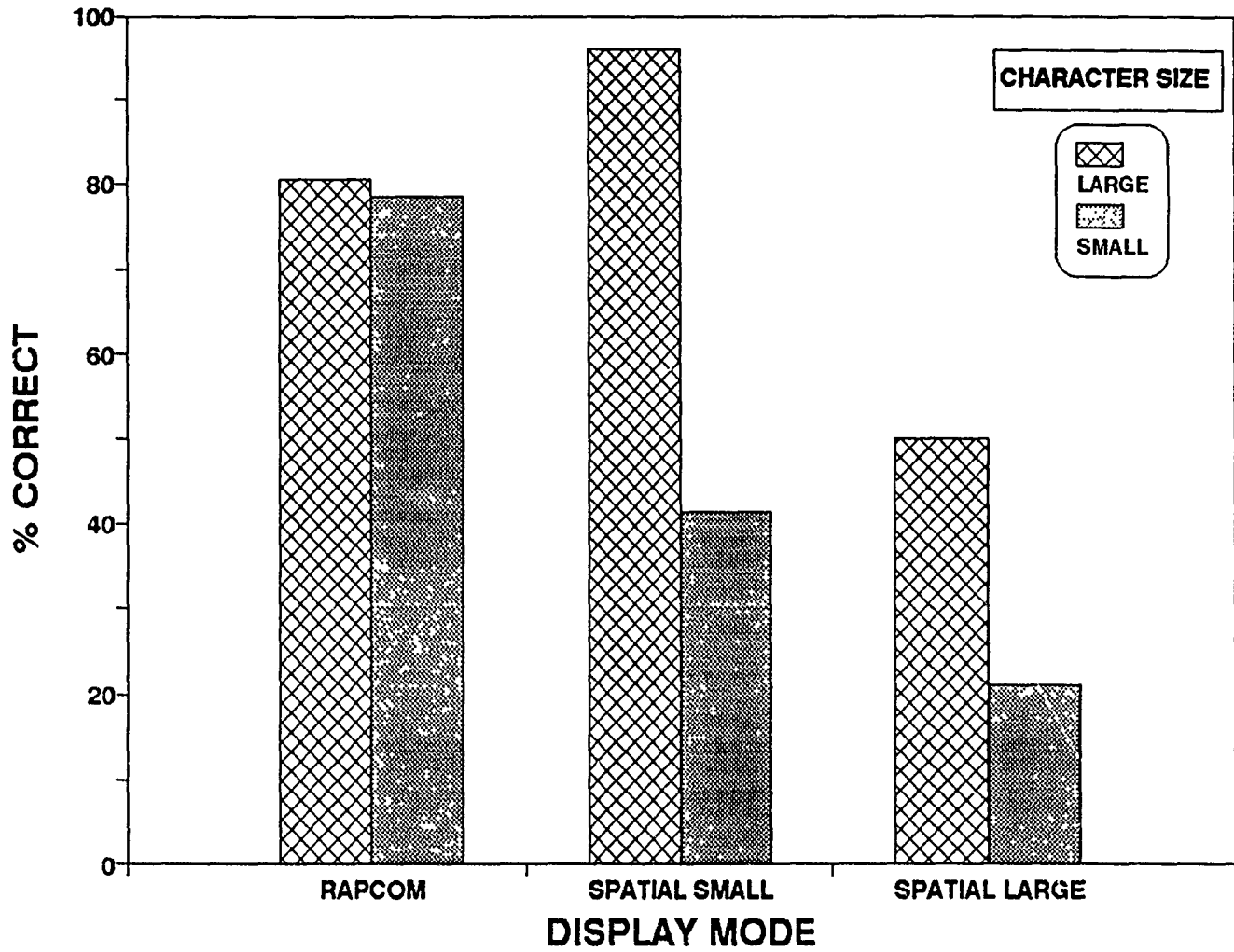
TOXICOLOGICAL VALUES IMPLEMENTED IN
TESTING OF HALON REPLACEMENT AGENTS

Timothy Scott Keen

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ABSTRACT

An international consensus to remove Chlorofluorocarbon (CFC) compounds from production and U.S. national policy to implement the resulting protocols has motivated the U.S. Air Force to embark on a program to find a suitable replacement for Halon 1211, currently used to extinguish flight line fires. This research addressed the feasibility of conducting a combustion toxicology (CT) program to assess the toxic products of the combustion interaction of JP-8 and the Group 1 or so-called "Near Term" candidate replacement agents for Halon 1211: HCFCs 123, 124, and 142b. A laboratory scale experiment benchmarked on large scale testing of a 150 ft^2 pool fire was developed on the basis of Froude scaling of the full scale fire to a 15 x 15 cm pan fire. A prototype apparatus was developed and investigation into the use of animal behavior methods as an indicator of human incapacitation was conducted. The result is a new method which may potentially be utilized for future toxicity studies

of the combustion interaction of current and future U.S. Air Force fuels with various fire extinguishants.

1. INTRODUCTION

The threat of ozone depletion and greenhouse warming has motivated the international community to mandate the replacement of halocarbon compounds used by various sectors of industry and the military. The Montreal Protocol, which went into effect in January 1989, limits the production of Halon and sets a schedule for its eventual phaseout. The U.S. Air Force (USAF) is a major user of chlorofluorocarbons (CFC's) such as Halon 1211 and Halon 1301 for fire suppression roles in aircraft, in computer and communications facilities, and in flight line fire fighting and has initiated replacement programs for the Halons. USAF discharges of Halon 1211 amounted to 783,000 pounds in 1986, over 28% of the U.S. total. The vast bulk of these discharges was due to the use of Halon 1211 in flight line fire suppression training. Today the use of Halons in training is virtually nonexistent as a result of USAF compliance with a national plan to replace CFC's with substances which have low Ozone Depletion Potential (ODP) and low Greenhouse Warming Potential (GWP). A USAF Near Term program to replace Halon 1211, used in suppressing flight line Class B fuel fires, is progressing and various candidate hydrochlorofluorocarbon (HCFC) agents are being considered as candidate agents. Future programs will assess Medium Term and

Long Term replacement strategies for the Halons. Toxicity testing of the replacement gases is mandated by the U.S. Environmental Protection Agency (EPA) and has in fact been partially carried out for a number of the leading candidates. The combustion toxicology (CT) of these candidates, both in a thermal degradation sense, and in combination with burning fuels, is not mandated by the EPA. A CT program had not been conducted in the past on the interaction of Halon 1211 with fuels because CT is a newly emerging discipline with many uncertainties as to test procedures and collection, evaluation, and interpretation of data.

Data received from the outcome of a CT apparatus needs to be formatted in such a manner which can be easily interpreted to be relevant to previous and future output or to actual situations encountered in the environment. The proposed format is to use Threshold Limit Values and Lethal Concentrations.

2. DISCUSSION

Threshold Limit Values(TLVs) refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers be repeatedly exposed day after day without adverse health effects. Due to a broad variation in individual susceptibility, however, a small percentage of subjects may experience discomfort from some substances at concentrations at or below the threshold limit; a smaller percentage may be affected more seriously by

aggravation of a pre-existing condition or by development of an occupational illness. In the case of humans smoking of tobacco is harmful for several reasons. Smoking may act to enhance the biological effects of chemicals encountered in the workplace and may reduce the body's own defense mechanisms against toxic substances.

Individual subjects may also be hypersusceptible or otherwise unusually responsive to some industrial chemicals because of genetic factors, age, personal habits (smoking, alcohol, or other drugs), medication, or previous exposures. Such subjects may not be adequately protected from adverse health effects from certain chemicals at concentrations at or below the threshold limits. An occupational physician should evaluate the extent to whichh such subjects require additional protection.

TLVs are based on the best available information from industrial experience, from experimental human and animal studies, and, when possible, from a combination of the three. The basis on which the values are established may differ from substance to substance; protection against impairment of health may be a guiding factor for some, whereas reasonable freedom from irritation, narcosis, nuisance, or other forms of stress may form the basis for others.

The amount and nature of the information available for establishing a TLV varies from substance to substance;

consequently, the precision of the estimated TLV is also subject to variation.

The TLVs issued in this report are recommendations and should be used as guidelines for good practices. In spite of the fact that serious injury is not believed likely as a result of exposure to tne threshold limit concentrations, the best practice is to maintain concentrations of all atmospheric contaminants as low as is practical.

Definitions. Three categories of Threshold Limit Values(TLVs) are specified herein, as follows:

1) **Threshold Limit Value-Time-Weighted Average(TLV-TWA):** the time-weighted average concentration for a normal 8-hour workday and a 40-hour workweek, to which nearly all subjects may be repeatedly exposed, day after day, without adverse effect.

2) **Threshold Limit Value-Short Term Exposure Limit**

(TLV-STEL): the concentration to which subjects can be exposed continuously for a short period of time without suffering from irritation, chronic or irreversible tissue damage, or narcosis of sufficient degree to increase the likelihood of accidental injury, impair self-rescue or materially reduce work efficiency, and provided that the daily TLV-TWA is not exceeded. It is not a separate independent

exposure limit; rather, it supplements the time-weighted average(TWA) limit where there are recognized acute effects from a substance whose toxic effects are primarily of a chronic nature. STELs are recommended only where toxic effects have been reported from high short-term exposures in either humans or animals.

A STEL is defined as a 15 minute TWA exposure which should not be exceeded even if the 8-hour TWA is within the TLV-TWA. Exposures above the TLV-TWA up to the STEL should not be longer than 15 minutes and should not occur more than four times per day. There should be at least 60 minutes between successive exposures in this range. An averaging period other than 15 minutes may be recommended when this is warranted by observed biological effects.

3) Threshold Limit Value-Ceiling(TLV-C): the concentration that should not be exceeded during any part of the exposure.

In conventional industrial hygiene practice if instantaneous monitoring is not feasible, then the TLV-C can be assessed by sampling over a 15 minute period except for those substances that may cause immediate irritation when exposures are short.

For some substances, such as irritant gasses, only one category, the TLV-Ceiling, may be relevant. For other substances, one or two categories may be relevant, depending

upon their physiologic action. It is important to observe that if any one of these types of TLVs is exceeded, a potential hazard from that substances presumed to exist.

The Chemical Substances TLV Committee holds to the opinion that TLVs based on physical irritation should be considered no less binding than those based on physical impairment. There is increasing evidence that physical irritation may initiate, promote, or accelerate physical impairment through interaction with other chemical or biologic agents.

3. RESULTS

A compilation of toxicological data pertaining to the components of hydrocarbons and predicted combustion products of hydrocarbons and hyydrochloroflourocarbons.

BASIC TOXICOLOGICAL DATA

COMPOUND	LC_{50}	REF.	TLV_{TWA}	REF.	TLV_{STEL}	REF.
C_3H_4O	13	b	0.1	a	0.3	a
Br_2	750	b	0.1	a	0.3	b
$COBr_2$	---		--		---	
$COCl_2$	---		0.1	a	---	
COF_2	360	b	2	c	5	c
CO_2			5000	a	30000	a
CO	1807	b	50	a	400	a
CH_2	472	b	1	a	2	a
Cl_2	293	b	0.5	a	1	a
HBr	2858	b	3	a	---	
HCl	4701	b	5	a	---	
HCN	484	b	10	a	---	
HF	1276	b	3	a	---	
H_2S	444	b	10	a	15	a
NH_3	---		25	a	35	a
NO	593	b	50	a	---	
NO_2	88	b	3	a	5	a
SO_2	2520	b	2	a	5	a

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4. CONCLUSIONS

The use of Threshold Limit Values to format combustion toxicology data output is a suitable solution to the question of how to interpret the results of animal tests in toxicological gas chambers such as the proposed apparatus used in researching halons.

ILLUSORY SELF MOTION

IN FLIGHT SIMULATION

Jeffrey H. Schmidt

Abstract

The objective of the current research effort was to
conduct a pilot study to investigate the effects of operator
control and type of texture pattern on the experience of
illusory self motion in flight simulation   The results
support the hypothesis that active controllers of a flight
simulation experience an illusion of self motion to a greater
degree than do passive observers of a flight simulation
Limited support is found for the hypothesis that the presence
of a wire grid texture enhances the illusion. Possible
confounds in the experiment are noted and plans for a new
experiment are given.

Introduction

The displacement of a perceiver with respect to an
environment is known as "self motion" (Warren, 1990)   A
passenger riding in a moving car is a common example of self
motion   The term "vection" has been used to describe a
highly compelling illusory perception of self motion.
(Dichgans & Brandt, 1978)   If a passenger is seated in a
stationary car, and an adjacent car begins to move, he or she
may feel a brief but compelling sensation that the adjacent
car is stationary and they themselves are moving

Dichgans and Brandt (1978) have shown that three variables of visual information contribute to the "compellingness" of vection: (1) the apparent velocity of the motion stimulus, (2) the spatial frequency of the motion stimulus, and (3) the size of the field of view. Vection strength increases in a linear fashion with an increase in stimulus velocity and spatial frequency, then asymptotes and declines in a U-shaped function. In general, larger fields of view produce more compelling sensations of vection.

These findings have formed the basis for research investigating vection experienced in fixed-based simulators. The variables of stimulus velocity and spatial frequency in vection research are equivalent to the variables of optical flow rate and edge rate used in self-motion (Owen, 1984) In addition, Hettinger (in press) stated that there are ways of scaling the variables that contribute to vection in flight simulators. Spatial frequency is analogous to the level of scene detail in visual display (e.g , high scene detail is equivalent to high spatial frequency, low detail is equivalent to low spatial frequency). The flight simulator has proven to be useful in investigating vection.

Other research has investigated the factors that underlie the perception of self motion Hettinger (in press) reported that research conducted over the past ten years by himself and his colleagues has centered on the identification of optical flow and texture variables that support the

perception of simulated self-motion.

They found that variations in optical flow (a joint function of altitude and forward velocity) as well as variations in texture density (i.e , spatial frequency or scene detail) have important implications for the perception of simulated self motion. They also found that in general, texture densities that are either very sparse (low spatial frequency, low scene detail) or very dense (high spatial frequency, high scene detail) result in perception of self-motion (e.g., detection of descent or change in speed) that are significantly less accurate than when moderate texture densities are used. Very low or very high optical flow rates also significantly interfere with the detection of descent.

Lastly, it has been documented that there is a connection between vection and simulator sickness. Hettinger (in press) found in an experiment using a generic flight simulator that vection is a necessary precondition for sickness in a fixed-based simulator. Subjects who did not experience vection did not become sick, while those who did experience vection experienced varying levels of illness (ranging from very mild to vomiting). Therefore, it was hypothesized that any display variables (like those mentioned above) that enhance the illusion of self motion would increase the probability of sickness In addition, Hettinger (in press) found that individuals actively controlling the simulation virtually never felt sick, whereas, those merely

observing the simulation often felt sick.

Thus, visual stimuli (of both a basic and applied nature) have proven to be relevant to the experience of vection. However, there has been little research investigating what contribution control makes to vection. That is, whether the illusion of self motion is stronger or weaker depending on if an individual is actively controlling some aspect of their flight simulation or merely observing the simulation.

Discussion of the Problem

The main objective of the current research effort was to investigate the possibility of a connection between operator control and the experience of vection. Since Hettinger (in press) found that vection was a precondition for sickness and that when reports of sickness occurred they virtually all came from passive observers, it was hypothesized that passive observers of a flight simulation would experience vection to a greater extent than active controllers.

The present study also investigated the effects that ground texture cues, (a wire grid displayed visually) may have on the experience of illusory self-motion. It was tentatively hypothesized that the grid would increase the sensations of self motion This would most likely be due to the grid providing an increase in edge rate information (Hettinger, personal communication, August, 1991)

Method

Subjects

Eight naive people served as subjects in the experiment. Seven participants were employees of various laboratories of the Armstrong Laboratories, and one was a graduate student from Wright State University. Four subjects had previous experience in visual flight simulators and four did not. One subject had their private pilot's license.

Apparatus

The simulated self motion events were generated on a Silicon Graphics 3020 computer and displayed at 30 Hz via an Aquastar IIIC high-resolution (1024 x 768 pixels) rear-projection system onto a 8 x 6-ft high-gain (55 Fresnel ridges/radial inch) Optixx Polylens screen. The subject sat on a B-1A seat in front of an "optical viewing tunnel" The screen, tunnel, and seat were all housed in a fully enclosed "visual bay" which kept out virtually all outside light.

The tunnel was comprised of a hollow wooden cube suspended on a sliding track above and in front of the seat The entire cube was painted black. Two holes were cut in the center of each wall of the cube A third hole was cut in a wooden panel and hung inside the middle of the cube Thus, these holes provided for a tunnel through which the subject viewed the events on the screen The tunnel allowed for a 60 degree field of view at four feet viewing distance A piece

of black cloth was hung from the bottom of the tunnel to
block out any light from the bottom of the screen. Another
black cloth was draped from the back wall of the visual bay
behind the seat to the left end of the tunnel. This kept out
any light that may have come through the visual bay.
Therefore, the only light visible to the subject came from
the scene itself through the optical tunnel hole.

An isometric or force-sensing control stick mounted on
the right arm-rest of the seat acted as a single integration
controller, such that application of a constant force away
from the observer resulted in a constant climb rate.

A "throttle" was mounted on the left arm-rest of the
seat. The throttle was only used by subjects to make
ratings. It did not in any way control the apparent motion
of the scene. A MicroVax II computer was used for real-time
data collection at a rate of 33 Hz.

Scene and Event Parameters

The scene that subjects viewed simulated forward motion
through a space representing an area consisting of points of
light or "stars" An upside-down "T" served as an aircraft
symbol that the subjects tracked The texture pattern was a
white grid placed over the starfield.

A vertical wind gust forcing function was used to cause
the aircraft symbol to either increase or decrease its
altitude No deviations of roll whatsoever were used in the
simulation

Design

There were two independent variables. Mode of control (active control of apparent self motion, passive observation of apparent self-motion) was crossed with texture pattern (texture present, texture absent) Each variable was manipulated within subjects. Vection rating was the dependent variable, recorded as percentage of throttle displacement, with 100% indicating the strongest feeling of self motion experienced.

A yoked pairs scheme was used to order the subjects sessions. A subject in the passive condition observed the output of another subject's tracking performance of the lead aircraft. Subjects participated in one session per day for a total of four sessions.

Procedure

After reading and signing an informed consent form any questions the subject may have had were answered Prior to the beginning of each session, subjects filled out the Simulator Side Effects Questionnaire (SSEQ). This was designed to assess the current state of physical health of the subject and consisted of 33 questions concerning any feelings of motion sickness and related discomfort the subject may have been feeling. A second questionnaire, the Motion History Questionnaire (MHQ) was completed at the start of the first session only This was was comprised of 7 questions designed to assess the subject's past history of

motion sickness and susceptibility and exposure to different motion simulators and other motion devices.

Subjects were informed of the rarity of motion sickness symptoms during flight simulation, but that they could be excused from the experiment at any time without penalty if they felt at all uncomfortable, and that they would be fully compensated for their participation up to that point.

Subjects then entered the visual bay and were given instructions for the control mechanisms. If a subject's first session was passive, instructions were only given for the throttle. Subjects were told that the "Full Back" position (the throttle pulled all the way back toward the subject) was to indicate that they felt no illusion of self motion whatsoever. If placed in the "Full Forward" position, this was to indicate that they were experiencing very strong sensations of self motion. "Very strong" sensations were operationally defined as the stars appearing to be still and one feels that they are being pulled through them. Throttle positions anywhere between these two extremes represented moderate sensations. Subjects then put on the headphones and microphone, as well as an eyepatch over their weaker eye. Viewing the scene with one's best eye helps to enhance the compellingness of the illusion. The subject then moved the stick to initiate the trial.

Subjects viewed a total of 40, 90-second visual motion displays over the four experimental sessions (10 per

session). The first session took approximately one hour (due to extra paper work), and the remaining sessions lasted approximately half an hour. In two of the sessions, they actively controlled their apparent motion through the starfield, while for the other two sessions, they simply observed their apparent motion For the "Active Control" task, subjects were asked to maintain co-altitude with the lead aircraft that appeared on the screen directly in front of them. For the "Passive" task, subjects did not perform any active control movements. They simply focused their attention on the movement of the lead aircraft throughout the duration of each trial.

All subjects were asked to continuously rate the strength of the illusory self motion they experienced throughout every trial. Subjects made the ratings by adjusting the throttle device to different positions representing the strength of the illusion. Subjects were reminded that this experienced strength could change at any time throughout the trial and to make changes in their ratings accordingly. Since subjects may have found it difficult at times to track the aircraft and make ratings concurrently, the experimenter reminded the subjects to adjust their ratings by saying the word "rating" over an intercom system

Before each Active Control session, each subject received four practice trials to familiarize themselves with

the tasks. One practice trial was given before a Passive session. Additional practice trials were given upon the subject's request Feedback in the form of root mean squared (RMS) altitude tracking error was given after each practice trial, but not after data collection trials. Subjects were merely told that they want to try to get the RMS number as low as possible.

At the end of each session, subjects completed the last page of the SSEQ and a Debrief questionnaire. The former was designed to assess the compellingness of the illusory self-motion, and the latter solicited the subjects' opinions on various aspects of the study. Upon the completion of all experimental sessions, subjects filled out a 10-item Final Debrief questionnaire, designed to assess how the subject's experiences of illusory self-motion changed across the all experimental sessions.

Results

At the time of the preparation of this report, data analysis for only four of the eight subjects was available. A two-way within-subjects full factorial analysis of variance was performed on the data. Table 1 presents the means and standard deviations for all groups All effects were significant at the 01 level of significance unless otherwise indicated

Figures 1 and 2 show the mean vection ratings for the main effects of control and texture pattern, respectively

Vection Ratings

	ACTIVE		PASSIVE	
	$\overline{X}$	S.D.	$\overline{X}$	S.D.
GRID	51.13	16.94	60.82	20.22
NO GRID	36.21	16.22	59.19	17.64

Table 1. Vection rating means and standard deviations for all groups.

As expected, significantly lower vection ratings resulted when subjects were actively controlling versus passively observing the simulation ($F(1,144) = 63.18$, $MS_{error} = 168.93$). Also as expected, the vection ratings were higher when the grid was present than when the grid was absent ($F(1,144) = 16.22$)

The interaction of control and texture pattern was also significant ($F(1,144) = 10.46$) Figure 3 shows the simple effect of control with the grid present, and Figure 4 shows the effect with the grid absent. The passive condition produced greater vection ratings than did the active both when the grid was present and when it was absent Additionally, Figure 5 shows that in the active condition, higher vection ratings were reported with the grid present than when it was absent. However, Figure 6 shows that the grid's presence or absence did not affect vection ratings in the passive condition
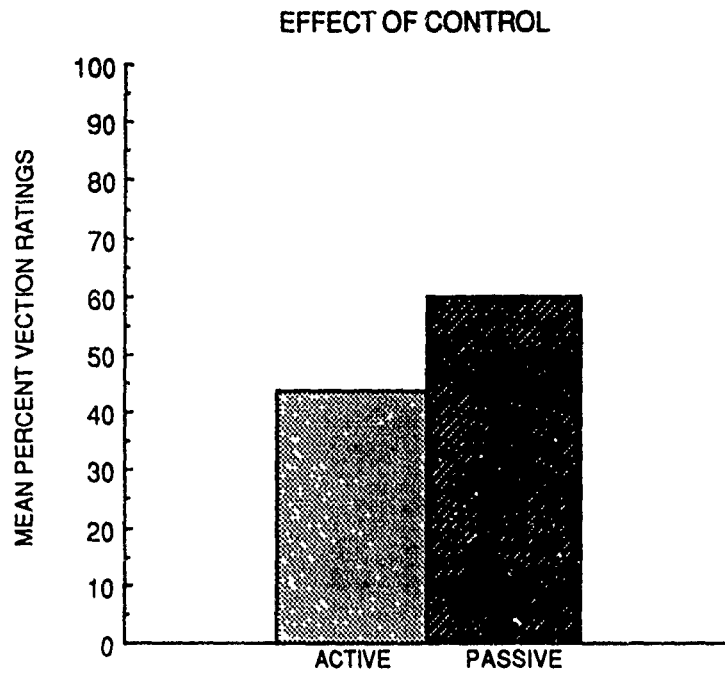
EFFECT OF CONTROL

Figure 1   The main effect of control on vection ratings.
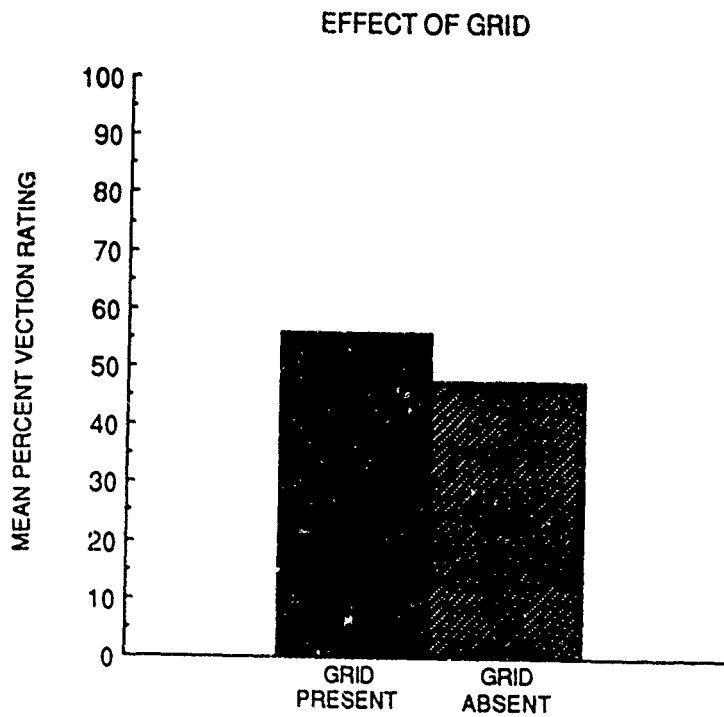
EFFECT OF GRID

Figure 2   The main effect of texture pattern on vection ratings

EFFECT OF CONTROL WITH GRID PRESENT
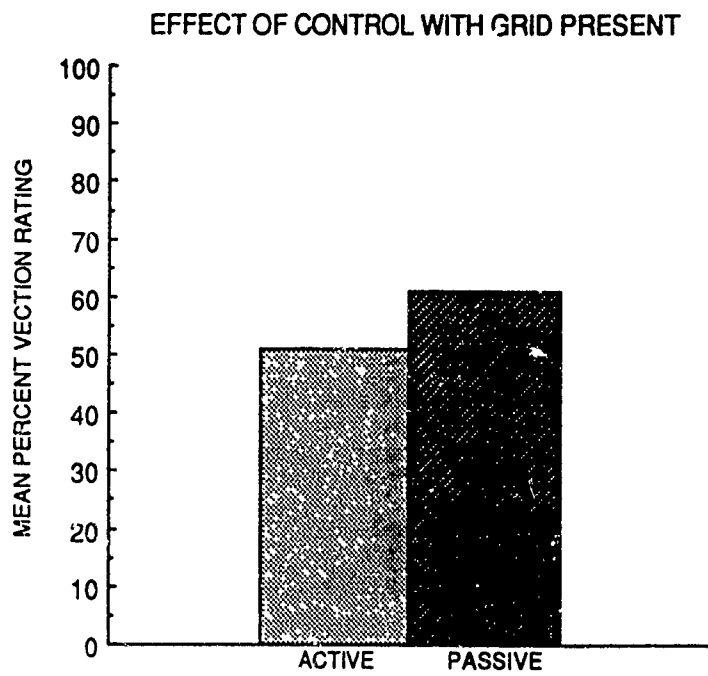
Figure 3. The effect of control with the grid present on vection ratings.

EFFECT OF CONTROL WITH GRID ABSENT
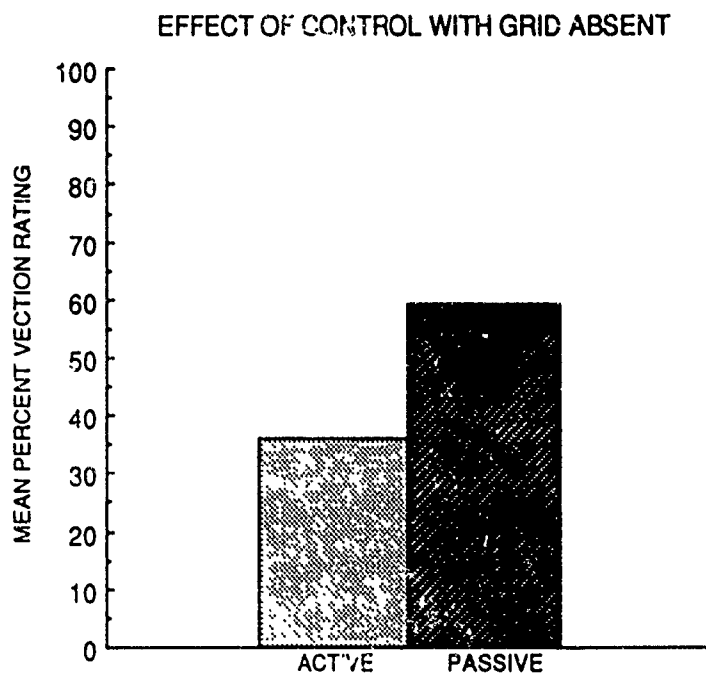
Figure 4 The effect of control with the grid absent on vection ratings

EFFECT OF GRID WITH ACTIVE CONTROL
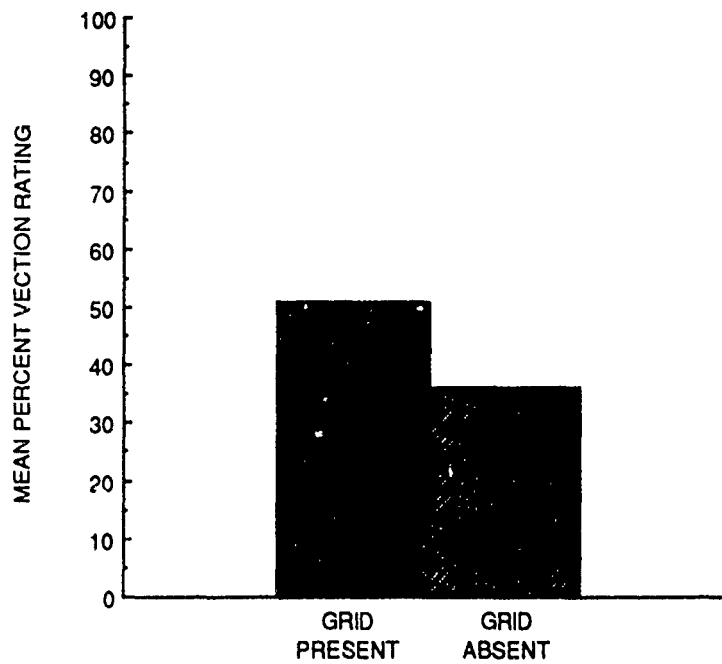
Figure 5. The effect of grid with active control on vection ratings.

EFFECT OF GRID WITH PASSIVE CONTROL
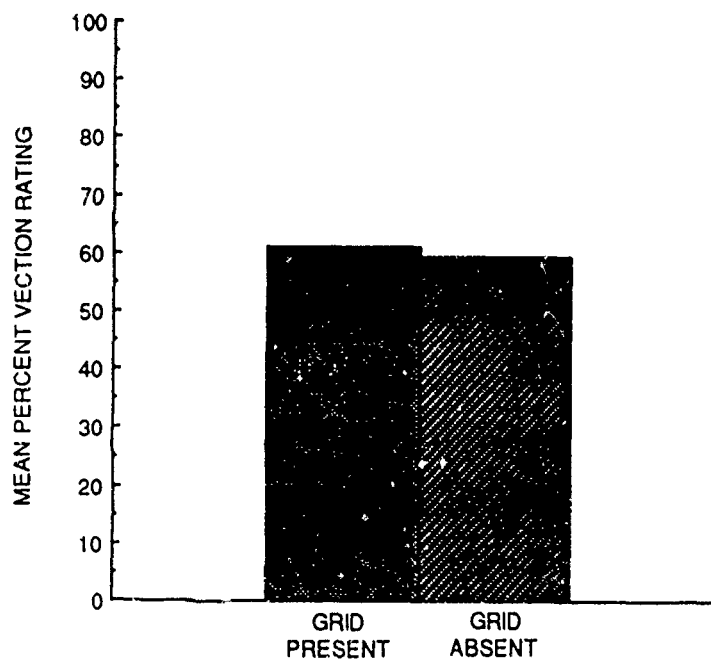
Figure 6   The effect of grid with passive control on vection ratings

Discussion

Since the analysis presented here was based on only four subjects, the results were interpreted as pilot information. That is, the results provided indications of whether our hypotheses were tenable or not.

The data support the hypothesis that passive observers of a flight simulation experience illusory self motion to a greater extent than do active controllers of a flight simulation. Overall, subjects reported significantly higher vection ratings when in the passive condition than when in the active condition. This supports the view of Hettinger (personal conversation, August, 1991) t 'ode of control i_ an important element in vection ""t as vection is an important element in simulator sickness. Although there were no reports of sickness by subjects in the present study, making subjects ill was not a purpose of the study. It merely indicates that although the simulation produced an illusion of self motion that was indeed visually compelling, it was not so much so as to make subjects physically ill.

Also, the significant main effect of texture supports the hypothesis that the grid would increase ratings of self motion. Subjects reported higher vection ratings when the grid was present than when it was absent. The grid most likely increased the edge rate information presented to the subjects, and as reported by others (e g , Owen 1984) such an increase helps to create the illusion of self motion

Significant simple effects bolstered the mode of control hypothesis. Vection ratings were higher for the passive conditions for both the grid present and grid absent conditions. There may be experimental confounds operating, however. The analysis of the data at each level of control suggests this

At the passive level of control, although ratings were high for both texture conditions, there was no statistical difference in the ratings when the grid was present or when it was absent. These findings do not support our hypothesis that the grid would increase vection ratings and indicate that something other than mode of control or texture alone are affecting vection ratings.

The difference in ratings may be due to two other factors: 1) differences in competition for attention for subjects, and 2) no control over where the subjects were looking during tasks. Subjects in the active condition had to engage in more activity than those in the passive Those in the former tracked the lead aircraft and made ratings, while those in the latter only made ratings The simultaneous tasks in the active condition may have provided for too much competition for subjects' attention It may have been difficult for subjects to make true ratings of the illusory self motion In addition, even though the passive subjects were instructed to watch the lead aircraft, they may have not felt the need to Since they were not tracking the

aircraft, they had the opportunity to look elsewhere on the screen.

Due to these possible confounds, a change will be made for a future experiment. A passive subject will press the force stick's trigger every time he or she sees the lead aircraft pass through a subjective "straight ahead" point on the screen This is merely an imaginary point that the subject judges as being in the center of the screen. The change will allow for equivalent attentional demands to be made on subjects in both passive and active conditions This will also encourage the passive subjects to monitor the lead aircraft as the active subjects do.

In summary, the present findings do suggest that passive observers experience vection more than active controllers of a flight simulation. Little support, however, was given to the secondary hypothesis of a grid enhancing the illusion of self motion. The data did, however, point out two possible flaws in the design of the active and passive tasks The changes mentioned above will be implemented in another experiment These changes will hopefully more clearly indicate the contributions of mode of control and texture to illusory self motion in flight simulation.

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ANIMAL TESTING IN COMBUSTION TOXICOLOGY OF HALON REPLACEMENT AGENTS

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ABSTRACT

An international consensus to remove Chlorofluorocarbon (CFC) compounds from production and U.S. national policy to implement the resulting protocols has motivated the U.S. Air Force to embark on a program to find a suitable replacement for Halon 1211, currently used to extinguish flight line fires. This research addressed the feasibility of conducting a combustion toxicology (CT) program to assess the toxic products of the combustion interaction of JP-8 and the Group 1 or so-called "Near Term" candidate replacement agents for Halon 1211: HCFCs 123, 124, and 142b. A laboratory scale experiment benchmarked on large scale testing of a 150 ft^2 pool fire was developed on the basis of Froude scaling of the full scale fire to a 15 x 15 cm pan fire. A prototype apparatus was developed and investigation into the use of animal behavior methods as an indicator of human incapacitation was conducted. The result is a new method which may potentially be utilized for future toxicity studies of the combustion

interaction of current and future U.S. Air Force fuels with various fire extinguishants.

TESTING ANIMAL INCAPACITATION

INTRODUCTION

Incapacitation versus Lethality

Traditionally the lethal concentration of a gas or smoke has been determined by exposing animals to various concentration levels until 50 percent of the animals die within a specified time period. This is defined as the LC_{50} value. A problem arises when the concentration necessary to incapacitate or impair the animal from performing a specific task is to be determined. The first and foremost concern is to define what constitutes incapacitation. Different tasks require various levels of cognitive ability and incapacitation in one situation is not the same as incapacitation in a different situation. Although behavioral studies are not new to toxicology, no standard test or set of tests for determining, both qualitatively and quantitatively, the level of incapacitation, have been widely accepted. The need for such a standard procedure is critical for determing the concentration levels at which incapacitation occurs in animals and the degree of that incapacitation.

DISCUSSION

Animal Testing Methods

Some of the testing procedures used in the past for determining changes in

animal behavior during and following exposure have been maze tests, homecage activity tests, open-field tests, startle response tests, rotorod tests, and wheel tests. Each testing procedure looks for differences between the exposed and control groups of animals. Each test has advantages and disadvantages and measures different parameters such as activity or cognitive ability.

Mazes

The two most commonly used of the maze tests are the "T" and Figure Eight. The "T" Maze is used post-exposure to test for a reduction in cognitive abilities. The "T" Maze does not require animal training and is basically a swimming test through a series of 6 to 9 T-shaped passages arranged to form a water-filled maze . The time it takes for the animal to complete the maze and the number of wrong turns it makes while attempting to complete the maze are recorded and compared to that of a control animal. The Figure Eight is a maze that is shaped like the number eight and is also used traditionally post-exposure . It differs from the "T" Maze in that it is not a swimming test and it measures the level of activity rather than the cognitive ability of the animal. A series of 8 photocells connected to a microcomputer record the level of locomotor activity. A major disadvantage of the Figure Eight Maze is that it takes 1-2 hours for rats to achieve habituation because of its level of complexity.

Open Field

The Open-Field Test measures animal activity by dividing a large square box into smaller equal squares and counting animal movement between

squares. This is done visually, with photocells, or by using a pressure sensitive grid. Due to its simplicity the habituation time for the Open-Field Test is about 15 minutes.

Homecage Activity

The Homecage Activity Test measures eating, drinking, rearing, and horizontal activity right in the animals home environment . The animal's rearing and horizontal activity is measured by mounting photocells on aluminum brackets outside the plexiglass cage and recording and logging the activity level via microcomputer (Figure 17). The animal's eating and drinking behaviors are also monitored in 24 hour increments. This appears to be the most comprehensive of the activity tests and suggest that homecage behavior provides one of the most sensitive and complete indices of toxicity.

Startle Response

The Startle Response Test detects the time for an animal to respond to a noise or some other stimulus. The animal is placed in a cage and allowed an adaptation period before the stimuli are administered. The mammalian startle reflex in a rat is exibited as an abrupt contraction of the flexor musculature that yields a momentary crouching posture . This test is useful in evaluating a suspected toxin's effect on the central nervous system. The disadvantage of this method is that the animals to rapidly adjust to the stimulus.

Rotorod

The Rotorod Test is a mechanical method for measuring animal incapacitation. After some training, a rat will remain on a rotating rod above an electrified grid to avoid being shocked. When the animal cannot remain on the rod or cannot jump back on the rod within a designated time, the animal is considered incapacitated . It should be noted that the level of incapacitation is still open to debate because it is possible that the rat could still perform other less complicated tasks.

Running Wheel or Rotating Wheel

A rotating wheel is a motor-driven exercise wheel on which the rat walks or runs for the purpose of testing cognitive ability. When the rat begins to slide or tumble it is said to be incapacitated . It is hypothetically possible to assign different levels of difficulty based on the speed of the wheel and to correlate them to varying degrees of incapacitation. Some researchers argue that walking and running are reflex type activities, hence the rotating wheel does not test cognitive ability. Further research is required in this area before definitive conclusions can be drawn.

The running wheel is a wheel that is driven by the rat walking or running on it and therefore is a measure of activity. A counter is attached to count the number of revolutions in a given time period. A disadvantage is that the animal may not run or walk voluntarily without some training or other method of encouragement. A baseline must be determined to compare the treated animals with the controls and it is difficult to observe subtle differences of significance.

CONCLUSION

An important issue is whether lethality or incapacitation should be used as the measure of CT effects. Each product of combustion will have a significant diff·rer.ce in concentration for lethality versus incapacitat;on. The use of incapacitation as a measure of CT effects runs parallel with general USAF desircs to assess mission capability. Unfortunately incapacitation experiments are much more involved to execute because animals may have to be trained in one or more behavioral patterns, the degradation of which is a measure of incapacitation. This involves a significant amount of additional time and expense to ready and execute the experiment. The potential use of cage behavior as a measure of incapacitation would significantly reduce the preparation time. One final point is that the degradation of behavic·· is a fairly subjective measure of performance while lethality is a very straightforward measure of effect. It can be argued that the re..,tionship between lethality and incapacitation is known for some of the major combustion constituents such as CO and HCN. Thus it may be possible to forecast the overall concentration of combustion atmosphere at which incapacitation would occur. Another possibility is to design the experiment with enough flexibility to accept either incapacitation or lethality studies.

CORTNEY VARGO

REPORT NOT AVAILABLE

AT TIME OF

PUBLICATION

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The Shared Meanings of Teamwork

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EXECUTIVE SUMMARY

The purpose of this project was to assess how members of teams in the Air Force interpret teamwork. It was predicted that some general themes, or interpretations, of teamwork would be shared by members of most teams. It was also predicted that on some teams, members would share a meaning of teamwork, and that on other teams, members would have different meanings of teamwork.

Information from team members was obtained in two stages. In the first stage, 54 military and civilian team members representing 21 teams in the Air Force were interviewed in small groups of 3 to 6 individuals, with a maximum of 3 individuals participating from each team. The information obtained from the interviews was used to develop a 3-part survey. In the second stage, all members of the participating teams were asked to complete the survey, and 00 completed surveys were obtained.

The survey required members of teams to rate 15 events that occur as a team works (e.g., The team makes decisions by consensus). They rated each event in terms of what it meant to them about teamwork. Members also rated their particular teams as to how well the team performed, how satisfied they were with the team, and how much team experience they had.

Results from the interviews yielded 7 themes shared by most team members:

   * A team must have a clearly defined and realistic goal.

* Cohesion and cooperation among team members are crucial to effective teamwork.

* Feeling comfortable with other team members may be achieved by understanding personality differences.

* Management should show commitment to teams by providing support.

* Commitment and motivation facilitate meeting the team goal, and make the team's work more enjoyable.

* Leadership and followership are essential to effective team performance.

* Team training should emphasize technical and social skills.

Results from the surveys revealed that.......

TABLE OF CONTENTS

INTRODUCTION

Purpose of the Shared Meanings of Teamwork

Work teams perform much of the work in the Air Force and team performance is critical to successful accomplishment of Air Force objectives. Therefore, it is useful to understand how effective teams function and how team perfc ^ce may be facilitated. One approach is to study shar   anings of teamwork among team members. It is proposed that if team members share meanings of the team's task and the process involved to achieve it, the team is likely to perform at a high level. However, if team members disagree as to what the task is or how to accomplish the task (i.e., team members do not share a meaning of the team's task), then team performance is likely to be low. The purpose of this study is to assess the degree to which team members share meanings of teamwork and to determine whether it is related to team performance.

Team members are assumed to interpret, or attach meaning, to "team events". A team event is anything that happens in and around a team as it works. Examples of team events are: the team norms, the facilities available to the team, the way in which the team leader was determined. These events tell team members something about the teamwork on their team. That is, team members interpret these events, or attribute meaning to these events. For example, the event: "The team works long hours" could be interpreted as representing the enthusiastic nature of the team. These interpretations of events can be expressed as psychological themes.

One purpose of this project was to determine whether events occurring as a team works are interpreted differently by members of different teams. Another purpose was to assess the relationship between level of agreement on a team and team performance. A second purpose was to determine some of the general themes or interpretations of teamwork that are common to most team members. In summary, the purposes of this project were to:

*   Identify the themes almost all team members use to
    characterize teamwork.

*   Identify the different characteristics that different teams
    use to describe team events.

*   Determine whether the degree of shared meaning of teamwork
    within a team is related to team performance.

Procedures Used to Obtain Information from Team Members

A two stage process was employed to obtain information from team members. First a sample of team members was interviewed. Then all team members were asked to complete a survey. First the interview stage will be described and then the survey stage will be described.

Interview Stage

Two or three team members from each team were interviewed in order to determine how team members define teamwork (i.e., their meanings of teamwork). It was necessary to learn (1) what happens as a team works and (2) how these team events are interpreted by members of different teams. The interviews were conducted in small groups of 3 to 6 individuals, and lasted approximately two hours. Specifically, 13 interviews were

completed involving 54 people from 21 teams. Each team selected the members to be interviewed based upon availability, interest, and scheduling.

The interviews were unstructured such that members could talk freely about what happens in the team and what these events tell them about teamwork. Questions such as the following were asked to initiate the conversation: "What characteristics are important to teamwork?" "Can you give specific examples?" "How do you describe the processes that occur in an effective team?" Additional probes and questions were asked in an attempt to elicit events and the interpretations used to describe these events.

All interviewees were assured confidentiality and the interviewer recorded all information by hand. No identifying information was noted (e. g., name, position, rank, or gender).

Survey Stage

The second type of information was obtained from surveys. All members of intact teams were asked to complete a three-part survey. The information ob'.ained from the interviews was used to develop the survey. Part one of the survey contained 15 team events that were frequently mentioned during the interviews. Team members were asked to compare each team event with every other event. They were to think about what each event in a pair meant to them about teamwork and then to rate the degree of similarity of the meanings of the team events. An example of this part of the survey appears in Appendix A.

The second part of the survey presented each of the 15 team events and 9 bipolar adjective scales. These adjectives were

frequently mentioned in the interviews to describe team events. Team members were asked to read each event and to think about what it told them about teamwork. Then they were to mark the point on each of the nine bipolar adjective scales that best indicated what the event told them about the team. An example of this portion of the survey is shown in Appendix B.

The third part of the survey presented team performance, team satisfaction, and team experience measures. Examples of these are presented in Appendix C. It took members approximately 60 - 90 minutes to complete all three parts of the survey. All members were assured of the confidentiality of their responses.

Overview of Results

The results from the interviews reflect the common interpretations shared by most team members. There were seven such themes or interpretations abstracted from the interviews. The survey results reflect the various interpretations of different kinds of team events. The details of the results from the interviews and from the survey appear in the following sections.

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TEAMWORK

INTERVIEW RESULTS

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Overview

The interview findings represent the common interpretations shared by most team members. The open-ended questions in the interview yielded the following seven themes as being important to most members of teams:

* A team must have a clearly defined and realistic goal.

* Cohesion and cooperation are crucial to effective teamwork.

* Feeling comfortable with other team members may be achieved by understanding personality differences.

* Management should show commitment to teams by providing support.

* Commitment and motivation facilitate meeting the team goal, and make the team's work more enjoyable.

* Leadership and followership are essential to effective team performance.

* Team training should emphasize technical and social skills.

While these themes have been stated separately here, it will become apparent that they are highly interrelated. Themes often tend to have some consistency and interrelatedness.

Theme 1: Clearly Defined Goals

The first theme centers on the importance of having a clearly defined and realistic goal, or a sense of purpose for the

team's existence. In the interviews, team members stressed that there must be a strategy or plan to obtain the goal. A team must be far-sighted and allow flexibility in either changing the goal or the strategy to meet that goal. Team members also felt that it is critical to have support from management in pursuit of its goals.

> "A team must have a well defined objective and
> know the process to reach the goal."

> "The goal or mission must be supported by those who are
> establishing the team."

> "Team members must be open minded and not do things
> because they have always done things that way."

Good goals were seen as one of the most critical aspects of effective teamwork. A team must know why it was formed and its mission. Ambiguous, unrealistic goals were said to demoralize team members and decrease members' motivation, cohesion and cooperation levels.

Another aspect of this theme is that all members must believe that the goal is worthwhile. In addition, management must also share in the belief that the team's goals are important and implement the team's products, or at least explain why not.

> "Leadership must share the team's goals."

> "We need feedback to understand how our product was
> utilized."

A strategy for meeting the team's goals was also noted as important. Schedules, tactical plans, milestones, and agendas were discussed as being helpful here. Finally, the team members

interviewed stated that it was absolutely necessary to have team members with the skills and abilities required to meet the team's goal. This was viewed as being critical to high levels of motivation.

Theme 2: Cohesion and Cooperation.

When asked, "What are some of the most important aspects of teamwork?", nearly every person interviewed said that there must be cooperation and cohesion among team members. There are several factors which most team members believe build cohesion and cooperation. For example, most team members said that if members volunteer to be on a team, they will be more willing to participate, thus, fostering cohesion and cooperation in the team. All team members pulling together for a common purpose was also mentioned as leading to cohesion.

> "All team members must buy in and agree that the goal is important."

> "A team must have a quality of mutual support by picking up the slack for each other."

Team members must be actively listen to and consider each others' opinions. Trust, honesty, loyalty, and respect among members were viewed as critical to cohesion and cooperation. A team can become cohesive when team members work together with openness and honesty.

> "Team members must be willing to accept minority opinions and be receptive to off-wall ideas."

> "Team members must respect each others' feelings."

> "What you say is what you do."

"All ideas are equal regardless of rank."

A willingness to accept mistakes and to treat problems as team problems rather than individual problems were also considered important in developing cohesion.

> "Let me help you and back you up."

> " 'We', not 'you', must change."

Social functions and a pleasant work environment were also thought to lead to cohesion and cooperation.

Theme 3: Personality Awareness

Many of the team members interviewed believed that the team's performance is enhanced by having a diversity of personalities on a team, but, they also recognized that diversity creates challenges. Therefore, they believed that there must be an awareness among team members of personality differences on the team. If team members can understand how and why people behave in certain ways, they may be less likely to offend others or to be offended by others. Personality awareness was thought to lead to team members feeling comfortable with each other and realizing that their teamwork could be enhanced because of the existing differences.

> "A team needs different expertise, different ideas --
> diverse personalities to bring things together."

> "It's important to try to identify personalities in
> order to understand how people operate."

> "People should overlook personality traits -- make
> adjustments -- and not be offended by them."

As team members feel comfortable with each other, open
communication develops, and cohesion and cooperation are
enhanced.

> "I want to feel like I can ask anything without being
> intimidated or feeling stupid."

> "Offer any constructive criticism."

Also, personality awareness was discussed as ultimately
improving the team's performance.

> "You must know when to recognize expertise."

> "Respect for others' expertise is important."

> "If rank and titles are eliminated, then respect can be
> given to expertise."

> "Creativity is a result of diversity."

Theme 4: Management Support

Team members stated that it is important for management to
work together with the team and to support the team. From the
beginning of the team's formation, management's guidance is
critical in helping to define goals. Thereafter, management can
facilitate the acquisition of needed resources. One of the most
frequently voiced sources of frustration for team members is that
management does not always support the team effort.
Recommendations of the team are oftentimes not considered
seriously and changes are not implemented. This can have a
negative effect upon the motivation and commitment of team
members. A constant complaint was that management only provided
"lip service" to the team.

> "If our manager does not believe in the team's
> goals, why should we?"

> "He is constantly changing our mission."

> "Management should have no preconceived notions of
> the team's product."

> "He should allow us to combine the team's meetings
> with our work day."

> "The time we have allotted to complete our team
> work should be proportional to management's support."

> "Management must be involved in the team's process.

It was suggested that management empower the team and offer it autonomy. However, if the team feels a need for guidance or a revaluation of its goals, team members believed that they should be supported by management.

Theme 5: Commitment and Motivation

Theme 5 centers on the importance of team members having motivation and commitment to the team and its goals. It may sometimes be necessary for members to do more than is required of them, such as helping out a fellow team member. Because of the self-sacrificing nature of teamwork, many team members believed that those who volunteer to be on the team will be more willing to devote time and effort to teamwork than those who have been assigned to work on the team. Indicators of commitment include: willingness to work, attending meetings, putting aside personal goals for the team's goals, and remaining dedicated and persevering through the team's difficult times.

> "Team members must do more than their fair share, and
> jump in if someone falters."

> "If you volunteer, you will be more dedicated and
> committed to the team's goals."

> "Willingness to sacrifice one's own objectives for
> the team's sake."

Motivation was also regarded by team members as critical to
effective teamwork. It is important for members to believe that
the goal is worthwhile so that they will want to attain it. This
will lead to team members completing assignments on schedule and
within the allotted resources. Having clearly defined goals
which are supported by management is key to motivating team
members. The goal must also be attainable and realistic. Once
the goals have been met, team members need to feel that the
outcome of their work is meaningful and useful. In addition,
team members said that they must feel that their individual
contributions as team members were worthwhile.

Many team members believed that motivation is especially
evident in members who have volunteered to participate on teams.
Motivated team members are likely to be enthusiastic and
ambitious. Not only will they accomplish objectives within the
allotted time frame and resources, they are likely to seek new
challenges for the benefit of the team. Many team members
expressed the belief that it is important to keep the team
motivated. They suggested that teams may be revitalized through
social activities.

> "Have a clearly defined objective, supported by those who
> established the team."

> "The outcome of individual efforts must be recognized."

> "Volunteers will show willingness to be a part of the team -
> -- be more enthusiastic."

"Completing assignments on schedule and looking for other things to do."

Theme 6:   Leadership and Followership

Leadership and followership were discussed as being essential components of teamwork. An effective leader was described as someone who had a long-range vision, and who could understand the team's task and process. A good leader was also characterized as being flexible, making sure that team members develop their skills, and encouraging team members to contribute their talents to the team. According to the team members interviewed, leader functions included keeping the team focused on the goal , reporting to the team client and/or manager, maintaining control over team meetings, allocating resources appropriately, and accepting mistakes.

"The leader should have a say in what the team norms are."

"Leaders look at process and content."

"Good leaders make sure members develop their skills."

The method for determining a leader was important to the team members. Some team members recognized that the team leader may not be a particular person. In other words, the role of the leader is fulfilled by different team members at different times. The leader in these cases is usually the team member with the most expertise in the problem area.

"The leader will change depending on expertise."

"Must get to know people, so the most appropriate person is leading at any given time."

> "Leaders will emerge based on areas of expertise --
> 'situational leadership'."

> "The leader is the expert."

Other team members believed that the leader must be designated. Some even stated that the leader is to be followed. When he or she makes a decision, the team should back him or her up and follow through on implementing the leader's decision. This leader should delegate effectively.

> "People back up a good leader."

> "The leader should keep the team informed of his decisions."

Still other team members believed that a leader should be elected, after getting to know all team members. They also stated that the leader should be aggressive and willing to "take charge", keep people involved, and be sensitive to others. Fairness was seen as a critical characteristic of an effective leader by nearly all team members interviewed.

Followership is another aspect of this theme. Followership was characterized by accepting others' ideas, being able to take on a leadership role, a willingness to work toward the team goals, giving other team members a chance to express their ideas, and giving up personal feelings to reach a team consensus. Good followers were also seen as not taking criticism personally, and as not personally attacking their teammates. They tend to take up the leadership role, or any other role, when necessary. In other words, they see "gaps" and fill them for the team. When things are not being done, they step in and do them. They also support

and follow the leader.

"Don't be quick to criticize."

"Accept your tasking, know your role."

"Once the leader is determined -- go with him."

"Take the initiative to get something done, if the
leader isn't there -- fill in the role of the leader."

It was also mentioned that good leaders must recognize that they must sometimes be good followers.

Theme 7: Training

Team members discussed the value of team training. Many suggested that the team's management and the team members should receive training in teams and teamwork when the team is formed. Furthermore, it was suggested that the team be trained together as a team, rather than having team members complete training individually at different times.

"People get back from training and no one else is
interested."

"We should all go through training at the same time."

Team members believed that training should include information on personality awareness. Learning effective communication skills in training was also suggested, because team members should understand the effects of verbal and nonverbal communication. In addition, learning to effectively use written communication, such as agendas, minutes, schedules was discussed.

"...need to understand personalities, and learn about
how different people look at the world."

"Must learn to participate and actively listen."

"Let everyone express their ideas."

"Should be aware of nonverbals such as sighing, body
language."

"An agenda is a communication tool."

It was thought that training should teach team members to
"play flat-out", and express their ideas, concerns in a
constructive manner. No disagreements should be hidden or
repressed. Most said that nonattribution should be a part of the
team's process.

Team members suggested that training should facilitate the
team process by helping the team to understand the usefulness of
team norms, and teaching the team how to establish and enforce
team norms. However, it was noted that these rules and norms
should be flexible enough to be corrected, or modified, if
needed. In addition, the rules and norms must be enforced
fairly.

"Must have clear norms."

"Norms must be followed."

"The teams rules should be corrected if they turn out to be
wrong."

"Must establish ground rules (e.g., don't talk all at
once)."

"No one can break the rules, no matter what their rank."

Summary

In general, the team members interviewed believed that clear
and realistic goals are the starting point for effective
teamwork. They also believed that team training and supportive
management are important. Goals, training and managerial support

were discussed as leading to high levels of cohesion and
cooperation, personality awareness, commitment and motivation
within the team. These characteristics were viewed as improving
team performance. Finally, effective leadership and followership
were thought to facilitate team performance.

MODELING COMPOSITE WINGS: AN OBJECT ORIENTED SIMULATION APPROACH USING MODSIM II

A.J.G. Babu and Jacqueline C. Schnepp

In this report, we describe a discrete event simulation model of an United States Air Force base-level aircraft maintenance organization serving a composite wing of aircraft. A composite wing is a mix of multiple types of aircraft under one commander in one general location. In contrast, a traditional wing, which we will call monolithic, contains many aircraft of the same type. For a composite wing consisting of F-16, F-15, and KC-135 aircraft, a prototype simulation model is constructed using a modular object-oriented design and the MODSIM II programming language. An arriving aircraft goes through flight line check and maintenance, obtains service at a selection of intermediary shops and finally gets reconfigured to take off. In reality, there would be more than twenty such intermediary shops. However, a simplified model is conceived for ease of prototyping. It consists of airframe repair shop, electrical shop, and environmental control shop in addition to flight line and reconfiguration shop. The prototype provides an understanding of the nature and scope of the problem as well as modularity and flexibility of the object oriented simulation approach. While demonstrating the modeling feasibility, it makes a case for the development of a complete model. A full scale model would help assess the maintenance resource requirements versus the sorties per aircraft. It can also be used to compare the cost and contributions of maintaining composite versus monolithic wings. The report concludes with suggestions for future directions of research.

INTRODUCTION

The Air Force is implementing General McPeak's plan of creating composite wings at key bases [1]. A composite wing consists of various types of aircraft under a single command. Traditionally Continental United States (CONUS) based wings are monolithic, containing many aircraft of the same type. In addition to the establishment of composite wings overseas at the forward bases, McPeak [3] opines that there should be some CONUS based composite wings for rapid deployment of the whole range of air capabilities to any part of the world. But the Air Force would still need to maintain monolithic wings - for example with 72 of the same aircraft -because of economies of scale [4].

Mountain Home Air Force Base (AFB), Idaho, and Pope AFB, N.C. will now house composite wings [2]. Two wings at Seymour Johnson AFB will be merged to form a composite wing consisting of KC-10 Extender tankers and F-15E Strike Eagle fighter-bombers [1].

The traditional Air Force structure consisting of monolithic wings do not readily form an efficient composite strike package. On the other hand it may be more expensive to operate and maintain composite wings.

DECISION PROBLEMS

The following considerations are to be taken into account in formulating the decision problems associated with the formation of the composite wings. For each candidate composite wing formation, 1) assess the operational benefits in terms of reduction of force vulnerability and planning cycle time as well as increased tasking effectiveness, 2) assess the reduction of operational costs by streamlining the management, especially, the upper level management, and 3) assess the cost increase

in the procurement and maintenance of aircraft maintenance resources (manpower, facilities, and equipment) and spare parts inventory for a given type of maintenance structure. Both the maintenance cost and sortie rate per aircraft are very sensitive to the type and extent of maintenance performed at base level and depot level. Since a composite wing is formed of some or all of the aircraft from certain monolithic wings, the resulting reduction of aircraft would result in reduction in maintenance expenses. Another important consideration is the economies of scale obtained with size or the number of composite wings formed. The interaction effect of geographically related composite wings may be significant.

With all these considerations, the overall problem (P1) is to decide on the formation of composite wings: when, where, what type and size? Where are these constituent aircraft drawn from? What is a sensible maintenance policy, i.e., how are the levels of maintenance defined and who should be authorized to perform these levels? The problem is dynamic in nature. It should respond to technological advancements as well as the ever changing political, military, and economic environments.

THE CURRENT USAF APPROACH

The integrated problem P1 above needs to be addressed simultaneously for an efficient solution. The United States Air Force seems to have made a critical decision in selecting the first three CONUS-based composite wings. The initial solutions look attractive in a short time horizon, but a sound long term strategic plan should take maintenance as well as operational factors into consideration.

Complex problems such as P1 are usually amenable for solution with

tactful simulation modeling and analysis [5]. Obtaining reliable data for such a modeling venture is impossible. However the type of data needed to describe two alternative system configurations (For example, a composite wing versus three monolithic wings) is similar. The data collection methods are similar. This may lead to similar biases in the collected data. The inferences made in comparing these configurations using such similarly biased data are highly reliable.

COMPOSITE WINGS MAINTENANCE SIMULATION

Since the problem P1 is beyond the scope of this project, we consider a more tractable portion of the problem. The problem P2 is to assess the maintenance resource requirements versus the sortie rate per aircraft of a Base Level Aircraft Maintenance (BLAM) facility serving a composite wing. We modeled the problem as a discrete event simulation.

Why Simulation works?

Simulation works because it deals with reality. We simulate models of real systems. We get closer to the system than any other type of modeler. We study the old system, collect data, understand first principles about the system, check out procedures in use before we start modeling, and we test proposed solutions against current operations or baseline designs. We do not force a system into a preconceived normative model. We strive to have our models used and our best alternatives implemented. We stay with a problem until a solution is implemented. We recognize that the model upon which we make our recommendations contains additional information and insights that are useful during implementation [6].

A prototype described below is developed using an object oriented

approach and the MODSIM II programming language. It is constructed to test the feasibility of an object oriented simulation approach. The composite wing consists of P-16, P-15, and KC-135 aircraft. An aircraft arrives at the maintenance facility randomly with interarrival time following a prespecified probability density function (e.g., exponential with mean 200 hours). An arriving aircraft is P-16, P-15, or KC-135 with prespecified probabilities (e.g., 0.5, 0.35. and 0.15 respectively).

The maintenance service is offered at the flightline, airframe repair shop (shop 1), electrical shop (shop 2), environmental control shop (shop 3), an reconfiguration shop. Each arriving aircraft gets served in the flightline, a selection of the three intermediary shops, and the reconfiguration shop. This selection of the intermediary shops is made for each type of aircraft using prespecified probabilities. For example, an arriving P-16 needs service at shop 1, shop 2, and shop 3 with probabilities 0.2, 0.4, and 0.1 respectively. These probabilities are 0.5, 0.3, and 0.45 for P-15, and 0.1, 0.35, and 0.5 for KC-135. Thus a given aircraft may get served by none, one, some, or all of the three intermediary shops. The service times at flight line, three intermediary shops, and the reconfiguration shop are all assumed to be independent and randomly sampled from prespecified probability distributions. For example the service time follows a normal distribution truncated at zero. This truncation would assure positive service times.

An arriving aircraft is served on a First Come First Served (FCFS) basis at the flight line. The selection of intermediary shops needed to serve this aircraft is determined. Upon completion of service at the flight line, an aircraft is available to be scheduled simultaneously at

its selection of intermediary shops. An intermediary shop would serve the aircraft needing its service on FCFS basis.

Advantages of Object Oriented Simulation

In an object oriented simulation, the system is modeled in terms of communicating objects and messages. Objects are capable of performing some predefined actions in response to requests. A message is a request for an object to carry out one of its operations. Messages specify what operations are desired, but not how those operations should be carried out. The receiver, the object to which the message was sent, must have methods defined for carrying out the requested operations. The method invoked returns an answer to the sending object. The power of object oriented programming lies in two conceptual foundations: encapsulation and inheritance. Encapsulation protects objects from change by restricting the access to the objects to those procedures that were put there to control access. Inheritance helps developers describe complex systems quickly and consistently by starting with generic descriptions and specializing them.

The Selection of MODSIM II

The MODSIM II programming language is selected for prototyping for two reasons. First, it is an object oriented simulation language. Modularity in MODSIM II improves reliability and reusability. Objects performing related functions can be grouped into modules. These can be put into libraries for reuse by other programs. Modules permit step-wise development, particularly by separating the definition module from the implementation module. It is a well supported language and is continually growing with the incorporation of several desirable simulation features

such as parallel processing and dynamic graphics. Second, TASC is developing an user friendly version of MODSIM II for use in Air Force simulations under a contract, Integrated Model Development Environment (IMDE) from our focal point, i.e., the Logistics Research Division of the Armstrong Laboratory (AL/HRG) located at the Wright Patterson Air Force Base. We may in the future be able to make a smooth transition to using IMDE for the development of a full scale composite wing simulation.

CONCLUSION

In this report, we pose a decision problem concerning the establishment of composite wings of aircraft. The overall problem to determine the locations of composite wings, and prescribe their size, time of establishment, and mix of aircraft. The operational benefits versus costs involved have to be systematically weighed in making these determinations. The problem is dynamic and sensitive to the technological, political, military, and economic changes.

We focus on a portion of this overall decision problem. It involves the assessment of the operational characteristics of a base level maintenance organization serving a composite wing of aircraft. We model this problem as an object oriented discrete event simulation. A prototype simulation is designed and coded using MODSIM II on a SUN 4/ SPARC Station. The listings and a description of this program is attached in the appendix. This prototype has demonstrated the proof of concept and made a strong case for developing a full scale simulation. Such a simulation would be helpful in comparing both sorties per aircraft and maintenance cost for operating composite versus monolithic wings. It can be designed to analyze the impact of various levels of maintenance and the

extent of maintenance skill cross training.

FUTURE DIRECTIONS OF RESEARCH

The natural extension of the prototype simulation described here is to build a working maintenance simulation model to assess the cost and maintenance implications of a composite versus monolithic wings under various levels of skill cross training and different allocations of maintenance tasks to a base level maintenance facility. TASC is developing IMDE, an user friendly simulation modeling environment using object oriented design. Since its simulation elements are written in MODSIM II, a smooth transition can be made in coding the simulation model in MODSIM II to coding in IMDE. IMDE's features would improve the simulationist's productivity.

ACKNOWLEDGEMENTS

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Individual Differences (Impulsivity) and Personnel Selection

Final Report

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Siem, Carretta, & Mercante (AFHRL-TP-87-62, 1988) found a relationship between performance on the Self Crediting Word Knowledge (SCWK) test portion of the BAT and pilot performance in Undergraduate Pilot Training (UPT). SCWK correlated 0.14 (p < 0.01) with pass/fail criteria for UPT candidates. One way to interpret these data is to note that subjects who passed UPT : took longer to answer on SCWK, had fewer total correct responses, and bet fewer points on the responses they did make. Even when overall verbal ability was statistically controlled there were smaller but robust differences in time to answer between successful and unsuccessful candidates. Those candidates who completed UPT tended to take longer for their responses. The authors interpreted this finding as a manifestation of a more cautious decision-making style exhibited by successful UPT candidates.

Siem (1991) tested 302 UPT candidates using various tests (BAT) including the SCWK test and the Activities Interest Inventory (AII). Siem found: 1) that response latency measures were related more closely to self-report personality measures than to cognitive response times, 2) that the risk-taking score was associated with a self-report measure of thrill seeking, and 3) that the performance-based self-confidence score was correlated with verbal aptitude but not with a self-report measure of self-confidence. A confirmatory factor analysis performed to examine the data structure provided a three factor model: 1) verbal self-confidence, 2) cautiousness, and 3) thrill-seeking.

What does all this mean mean? We know: 1) pilots need adequate levels of thrill-seeking or they won't fly jets, 2) cautious decision makers do better in UPT, 3) thrill seeking and cautious decision making (the opposite of impulsivity) are components of what purveyors of the "Big 5" call Surgency, or that Eysenck calls Extraversion, and 4) Surgency, by itself, is not strongly associated with pilot characteristics (Ashman & Telfer, 1983).

What would we like to know: 1) will a composite score incorporating high thrill-seeking and low impulsivity, essentially a decomposition of surgency, predict pilot training success, 2) if such a situation occurs what is the magnitude of the relationship, and 3) are there particular "impulsivity factors" associated with poor training performance?

Method

Subjects:
   One hundred fifty-three AFROTC Flight Screening Program (FSP) candidates tested during the summer of 1991.   One hundred forty-four subjects yielded usable data.

Procedure:
   -The FSP candidates were tested on the BAT.
   -Substituted for the Automated Aircrew Personality Profiler were 169 items
      from:
      -Barratt & Patton Impulsivity Scale items (impulsivity)
      -Gerbing, Ahadi, Patton Items - 12 Factor (impulsivity)
      -16PF Scales
         -Surgency   (Extraversion)
         -Ego Strength (Impulse control)
         -Superego Strength (Environmental Conformity)
         -Premsia   (Tendermindedness/Dependency)
         -Protension (Anger, Introverted Suspiciousness)
         -Autia (Unconventional Behavior/Imaginativeness)
         -Q3 Self-sentiment Strength (Sense of Identity)
         -Q4 Ergic Tension (Undischarged Instinctual Energy)
      -GZTS Restraint Scale
      -MMPI Impulsivity Items

   -The FSP candidates then completed the regular pilot screening program in
      prop-driven   aircraft.
   -Criterion variables include:
      -Pass/Fail
      -Academic Average Score
      -Check Ride Scores
      -5 Point Likert Scale overall rating of Pilot Competency by AF Pilot
         Instructors

Results

   One hundred fifty-three subjects were tested during the BAT portion of the study. One hundred forty-four subjects completed all the testing and comprise the subject pool.   As of September 27, 1991 the data from these subjects is in the custody of OAO Corporation   (Air Force contractor in charge of BAT testing) employees at Brooks AFB, Texas.   SAS programs for analyzing these data were written at Brooks by Dr. Patton and Ms. Brady.   These programs are now resident on the Baylor University VAX mainframe computer.   When OAO provides the data files to Dr. Patton they will be uploaded onto the Baylor VAX and analyzed.

   Dr. Patton gave an "Exit Lecture" on August 28, 1991 at Armstrong Laboratory, HRD, HRMA, Brooks AFB, Texas.   When these data are analyzed Dr. Patton has agreed to return to Brooks to provide a briefing on the results and their meaning.

PROTOTYPING GAIDA: A LEARNING AND DEVELOPMENTAL PROCESS

Steven W. Hancock, Summer Research Associate

Abstract

The automation of instructional design is a subject of great interest to people involved in education and training. The military is one entity that is heavily involved in education and training and would profit from the automation of instructional design. Armstrong Laboratory's Human Resources Directorate is implementing and testing the feasibility of these ideas. The GAIDA (Guided Approach to Instructional Design Adviser) project is testing the idea that a novice can produce effective computer-based instruction by merely following appropriate guidance given through a computer-based system. In order to test the feasibility of this idea a prototype was built using Asymetrix's ToolBook®. This prototype will be used to conduct research in order to determine whether a system of this type is effective. The knowledge gained from the prototyping process and this research will guide further developments of GAIDA.

Introduction

In recent years computer-based instruction (CBI) has become a very popular medium for teaching and training. However, because of a lack of expertise in both the design of instruction and the use of computer-based technologies to present instruction, CBI has not always shown to be effective (Spector & Muriada, 1991). In addition, the time it takes

to produce quality CBI is sometimes not economical (Spector & Muriada, 1991; Li & Merrill 1990). In order to solve these problems two questions need to be addressed: (1) Is it possible to automate the development of CBI in order to reduce costs? and (2) during such automation, is it possible to provide the necessary expertise in order to produce effective instruction? In an attempt to answer these questions, researchers are striving to automate the production of CBI. Projects exploring the possibilities of automation of this type are underway at Armstrong Laboratory's Human Resource Directorate at Brooks AFB in San Antonio, Texas.

One project underway at this time is the Guided Approach to Instructional Design Automation (GAIDA). GAIDA is based upon the ideas of Prof. Robert M. Gagné. Under his direction the feasibility of automating instructional design is being tested. Gagné believes that the computer-based instructional process can be simplified by merely providing the developer with guidance and then allowing the developer to produce instruction (Gagné, 1991a; Gagné, 1991b). Once the guidance is given the person should be able to create CBI without concern for the intricacies of the computer.

One of the first steps in the development of an actual system is to test whether it is possible for a novice to produce adequate instruction based upon Gagné's type of guidance. In order to test this idea it became necessary to build a computer-based prototype that would enable users to receive guidance and develop CBI. With the GAIDA

prototype, research can be conducted to help answer the two questions discussed previously.

The purpose of this paper is to report on the development of this prototype. This information documents an early phase of the GAIDA project and provides a source of information for future developments of GAIDA. The development of this prototype was the project assigned to the author during a ten-week summer research program at Armstrong Laboratory's Human Resource Directorate.

Functional Prototype Development: The Problem

To test his ideas of instructional design guidance, Gagné chose to implement two prototypes. At the present only one of these, the pulmonary function test, is completed. The other prototype is based on a check-list procedure for a functional check of the gun in an F-16 aircraft. Only the prototype based on the pulmonary function test will be discussed in this paper.

In order that a prototype could be built that would guide a user in constructing a piece of CBI, Gagné first designed a paper version of the communications and interactions that should take place (Gagné, 1991b). These communications were specific to the pulmonary function test which was the focus content of the first prototype, and they were based on Gagné's nine events of instruction (1985). Gagné's fundamental hypothesis is this: By providing a user of the system with the nine

events and suggestions and examples to show how to implement them, novice CBI developers will be able to produce quality instruction.

In order to implement these ideas, the basic structure of the program had to allow users to view the instructional guidance and then switch to another file where they could implement some instruction based on that guidance. In addition, it was believed that these functions had to take place in a very simplistic manner so as to allow users the chance to concentrate on the development of instruction and not be distracted by the intricacies of the computer environment. The appropriate level of this simplicity is a question that is discussed later in this paper.

Each one of these demands came with its own problems, and these problems can be classified into three areas: (1) The development of resources for users; (2) the development of the background architecture of the program; and (3) the development of a simple user interface. Each of these areas will be discussed in more detail below.

Resource Development

In order to allow users to develop CBI without requiring that they be knowledgeable in computer operations, it became necessary to provide them with all of the computer resources that they would need. These resources fall into two categories: Graphics and functional computer code.

Graphics. The production of quality CBI necessitates the use of graphics. Consequently, it was deemed necessary that the users be able to access graphics, without creating them, and put them into their lesson. In the first stages of the prototype development this presented a serious problem because ToolBook® (1.0) enforced a sixty-four kilobyte memory limit per computer display. One or two color graphics brought in from an outside source easily exceeded this limit. Because of this problem, most of the work on the prototype was done without graphics. This problem was solved through the acquisition of ToolBook®'s updated version (1.5) which no longer enforced this limit.

Functional Computer Code. Not only are graphics important to the creation of an effective lesson, but it is also necessary to provide some interactivity through the use of programming. However, for the sake of simplicity it was decided that the program should not require users to do the programming. In fact the resultant prototype allows users to develop a CBI lesson by simply clicking buttons with a mouse, accessing pop-up menus, and typing on a keyboard.

To accomplish this, it was necessary to have the computer code for the lesson already built into the prototype. By doing this, each display that a user constructs will already "know" how to teach the information it is given.

This computer code was built in a two-step process. First, it was necessary to build a demo lesson of the pulmonary function test using the nine events of instruction. Since the guidance is based on the nine

events of instruction, a demo lesson would provide us with computer code that would correspond to this guidance. The code used in this lesson was generic so that it could control any lesson with a similar structure. Once this demo lesson was built, the code was stripped out and put into the GAIDA prototype. Additional changes were made so that this code could be accessed by the user of the program. Because the guidance in the prototype is specific to a particular outcome of learning (executing a procedure), it was possible to build code to run any procedural lesson that would also correspond with the guidance.

Background Architecture Development

Once the resources were developed, the program required some mechanism to allow the user to work with these resources. This is the main function of the background architecture.

The biggest problem in creating the background architecture was that it was necessary to allow users to function in two environments so that resources could be moved back and forth. First of all, users were placed in a student environment. This environment has been identified as the "to be learned" environment, and this is where the user receives guidance. Second, users needed access to a new file in which they could develop their own lesson. This second environment has been identified as "to be taught." In addition, it was necessary to exercise some control over the new lesson until that lesson was completely finished. By exercising such control, users are not left entirely on

their own to develop the instruction. ToolBook® allowed this type of control between the two environments through the use of dynamic data exchange (see appendix A for the source code).

Once this type of mechanism was in place, it became a much simpler matter to control the use of resources while still providing a very simple user-interface. For example, if a user is developing a lesson in an external file, the communication link to the main program would allow it to do many tasks that a user would otherwise need to do, such as programming and computer display design. Because the main program is able to do these tasks, the screen does not need to be cluttered with devices that would allow the user to do the same tasks.

User-Interface Development

As mentioned above, solving some of the complex problems in the background architecture resulted in a much simpler user interface. Developmental tasks can be accomplished without the action of an outside user. Because this is the case, developing the user interface required less time and was mainly a problem of deciding how the program should look to the users.

Appearance plays an important role in the simplicity of a program. If the screen were jumbled with a number of different objects, the simplicity of that program would suffer. Therefore, the number of controls needed for the prototype was limited to a few buttons and a pop-up menu for the placement and movement of graphics and fields (see
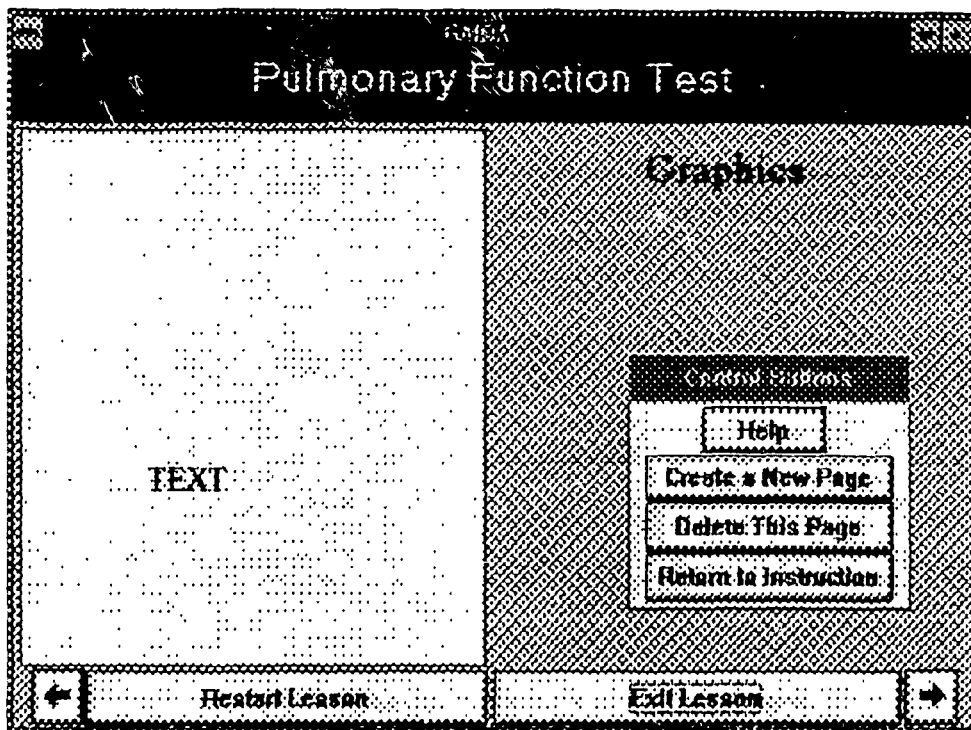
Figure 1. The controls for the user are contained in the control box and in pop-up menus for both graphics and fields.
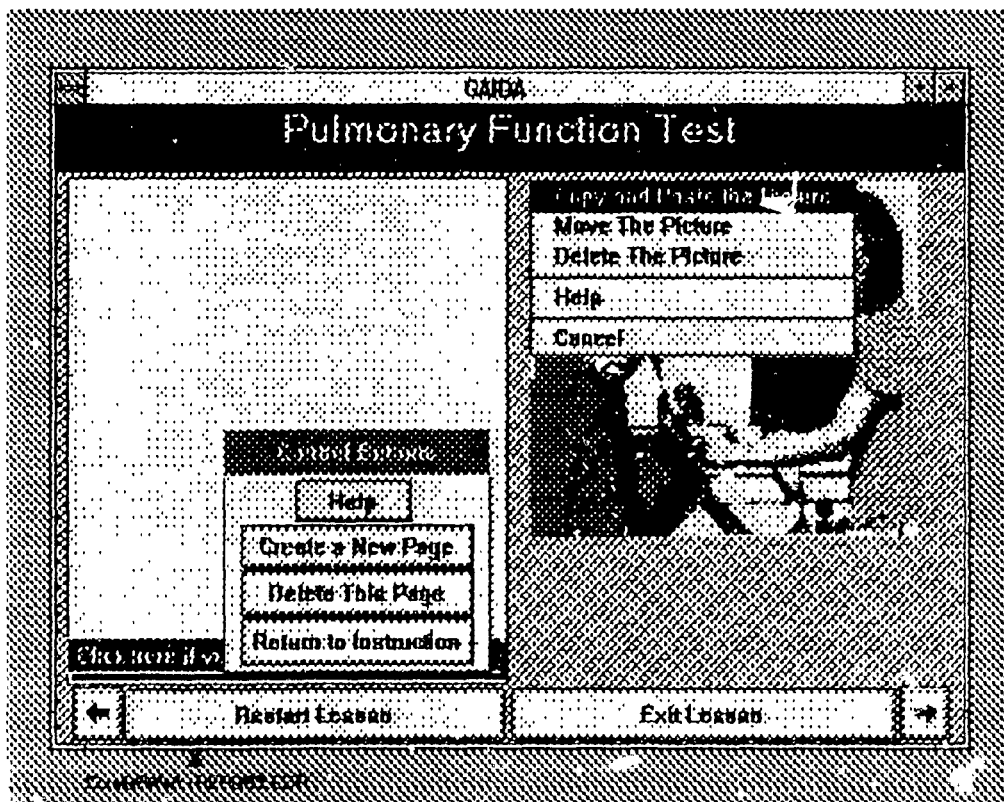
Figure 2. The screen is divided into a section for graphics and text. The dimensions sometimes change, but the signifying color stays the same.

figure 1). The buttons were labeled in a very straightforward manner that identified their purpose.

The screen layout was separated into two parts: a section for the graphics, and a section for text (see figure 1 & figure 2). The purpose of this was to eliminate confusion as to where users should type in their messages. Each of these areas were clearly identified by a color.

In addition to the simplicity of the structure, a help function has been provided. This help function can be accessed at the beginning of the program and then at critical parts throughout the program to aid the user in running the software. These items should provide a basis for a much simpler program to allow users to concentrate on developing instruction and not worry about learning how GAIDA works.

Results of the Prototype

The act of prototyping in and of itself is a knowledge-gathering function. When one is forced to actually implement ideas that have not been implemented before, knowledge is gained about the feasibility of these ideas. The knowledge gained through the prototyping process and the functional prototype itself are the products of the ten-week research project engaged in by the author. These two products will be discussed subsequently in greater detail.

The Prototype

The prototype that deals with the pulmonary function test is completed at this point, and it appears to be adequate to its research task. As yet no major flaws have been discovered which might arrest users. The instruction that a user produces as a result of the system can be labeled as traditional, page-turning CBI from an instructional standpoint, but further developments will improve this feature.

The prototype will not only accomplish its main function of enabling Gagné and other Armstrong Laboratory scientists to conduct research, but this prototype should also be valuable to any further developments of GAIDA by providing initial ideas of how GAIDA's interaction should take place.

Knowledge Gained Through the Process

During the prototyping process many questions about GAIDA were asked and answered, but probably the most valuable piece of information that was gained was that it is possible to implement Gagné's ideas concerning automation using ToolBook® and to implement them in ways that are effective. It appears possible to provide computer-based instructional design by merely giving guidance to the novice and then allowing the novice to produce a piece of instruction. However, whether that novice can create effective instruction will need to be answered when this instrument is tried out in the field.

During the prototyping process, questions arose as to how simple this program should be. These questions can be stated in another way:

How simple or complex does GAIDA need to be in order that a novice can create effective instruction? Of course a question of this type cannot be answered simply through the prototyping process, but more knowledge will be gained as this prototype is evaluated in the field. The most important information that we gained about the simplicity of the system is that it is possible to make the system quite simple. This first version is very simple and could certainly be more complex. In order to allow the system to produce instruction that is much more interactive, users will need to participate more actively in the programming process, or the software will need to become much more sophisticated.

One final note that needs to be mentioned about the simplicity of this system is that some of its simplicity comes from the fact that Gagné has already analyzed the content (pulmonary function test) and gives suggestions to users on how to teach that specific content. However, in future versions of GAIDA, the suggestions that are given as guidance will need to be specific to a learning outcome (executing a procedure) and not to the content itself.

Conclusion

During the ten week summer research program which I spent at Armstrong Laboratory's Human Resource Directorate, I produced a functional prototype that will be used as a research instrument. This prototype guides a novice instructional designer through the steps needed to produce a piece of quality CBI. The guidance given consists of Gagné's nine events of instruction. In order to produce such a

prototype, certain problems with the programming and instructional design aspects were overcome.

The prototyping process confirmed the possibility of implementing Gagné's ideas but raised additional research questions concerning instructional design automation that will need to be addressed in the future. The resultant product should be able to provide some valuable information during field research that will aid in further development of these ideas into a more complete GAIDA system for the future.

Finally, additional prototypes should probably be more complex in order to shed more light on the level of complexity that is adequate for the novice. However, it must be remembered that as long as a program provides the necessary power, simplicity is favored.

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Appendix A: Source code to control communication
between the "to be taught" environment and the "to be
learned" environment.

```
Script for button id 23 of background id 0.


--determines whether a new book is being created or not
to handle buttonUp
    if version of this book = one then
        send NewBook
    else
        send GoToBook
    end
end

to handle NewBook
    local thisHandle, lastPage, txt
    pop sysHistory into LastPage
    --parts of this script were provided by Asymetrics
    set sysCursor to 4
    --quit if runtime version
    if sysruntime is true
        set sysCursor to 1
        request strNoRuntime()
        break to system
    end

    --force a new book, despite their startUpBook
    set sysLockScreen To true
    get StartUpBook
    if it is not null
        set StartUpBook to null
        run "toolbook.exe" minimized
        set StartUpBook to it
    else
        run "toolbook.exe" minimized
    end

    --check if a book is running in another instance
    getRemote "this book" application toolbook
    if it is null
        set sysCursor to 1
        request strCantFind("toolbook.exe")
        break to system
    end

    --establish properties of the new book
    executeRemote "Hide MenuBar" application ToolBook topic "(Untitled)"
    set sysSuspendMessages to false
    set sysLockScreen to true
    go to page "firstPage"
    set sysLevel to author
    select page "firstPage"
    send copy
    go to page "start"
    set sysLevel to reader
    executeRemote "set sysSuspendMessages to false;" &\
    "set focus to null;send paste" application toolBook topic "(Untitled)"

    if name of this page = "start" then
        set sysLockScreen to true
        go to page "firstEvent"
        set sysLevel to author
```

```
        select page "firstEvent"
        send copy
        go to page "start"
        set sysLevel to reader
        executeRemote "set focus to null;" &\
        "send paste" application toolBook topic "(Untitled)"
end

If name of this page = "event2" then
        set sysLockScreen to true
        pop sysHistory into LastPage
        go to page "secondEvent"
        set sysLevel to author
        select page "secondEvent"
        send copy
        set sysLevel to reader
        executeRemote "set focus to null;" &\
        "send paste" application toolBook topic "(Untitled)"
end

--Deletes the first blank page of the new book
ExecuteRemote "set sysLockScreen to true;" &\
"go to page 1;" &\
"set sysLevel to author;" &\
"select page 1;" &\
"send clear;" &\
"set sysLevel to reader;" &\
"set sysLockScreen to false;" &\
"set pageNumber of page firstPage to 1" application Toolbook topic "(Un
set sysLockScreen to false
set sysSuspendMessages to false
set bounds of mainWindow to 12,21,596,432
getRemote "sysWindowHandle" application toolbook topic "(Untitled)"
put it into ThisHandle
executeRemote "send sizeToPage" application ToolBook topic "(Untitled)"
go to LastPage

--brings the other window to the front.
set sysSuspend to false
get bringWindowToTop(ThisHandle)
set sysSuspend to true

--saves the newly created lesson
set it to null
Ask "Type in the name you will use to save the lesson you will create."
"  Don't use more than 8 letters before the .tbk extension (e.g. lesson
if It = null then
        set sysCursor to 1
        setRemote "sysChangesDB" to "false" application toolBook topic "(Un
        executeRemote "send exit" application toolbook topic "(Untitled)"
        break to system
end
put it into BookName

--checks to see if they have entered a correct name
if CharCount(BookName) > 12 or charCount(bookName) < 5 then
        request "The name you have chosen can not be used." with OK or Help
```

```
        If it = help then
            request "       The name should consist of 1 to 8 letters follove
            " the extension .tbk.  For example:  MyLesson.tbk"
        end
        set sysCursor to 1
        setRemote "sysChangesDB" to "false" application toolBook topic "(Un
        executeRemote "send exit" application toolbook topic "(Untitled)"
        break to system
    end
    if chars (CharCount(BookName) - 3) to CharCount(BookName) of bookName <
        request "You have entered and incorrect extension.  It should be .t
        If it = help then
            request "       The name should consist of 1 to 8 letters followe
            " the extension .tbk.  For example:  MyLesson.tbk"
        end
        set sysCursor to 1
        setRemote "sysChangesDB" to "false" application toolBook topic "(Un
        executeRemote "send exit" application toolbook topic "(Untitled)"
        break to system
    end
    --saves the new lesson
    executeRemote "save as" && quote & bookName & quote &\
    ",false" application toolbook topic "(Untitled)"
    set bookName of this book to bookName

    --checks to see if there is another file by that name
    getRemote "sysError" application toolBook
    put it into chek
    set it to null
    while item 1 of chek = "file exists"
        ask "There is already a file with that name.  Please choose another
        if It = null then
            set sysCursor to 1
            setRemote "sysChangesDB" to "false" application toolBook topic
            executeRemote "send exit" application toolbook topic "(Untitled
            break to system
        end
        set bookName of this book to it
        executeRemote "save as" && quote & it & quote &\
        ",false" application toolbook topic "(Untitled)"
        getRemote "sysError" application toolBook ·
        put it into chek
        set it to null
    end
    set version of this book to "two"
    set sysCursor to 1
    --bring new lesson back to the top
    get bringWindowToTop(ThisHandle)
end

to handle GoToBook
    --This handler pastes in subsequent pages to the lesson depending upon
    --which event of instruction the user is in.
    local lastPage, BookNam
    system Counter
    put BookName of this book into BookNam
    set sysSuspend to false
```

```
Conditions
    When name of this page = event2
        if counter <> "event2" then
            set sysLockScreen to true
            pop sysHistory into LastPage
            go to page "secondEvent"
            set sysLevel to author
            select page "secondEvent"
            send copy
            go to LastPage
            set sysLevel to reader
            executeRemote "set sysSuspendMessages to false;" &\
            "set focus to null;send paste;" &\
            "set sysSuspendMessages to true" application toolBook topic
            put "event2" into counter
            send getLesson
        else
            send getLesson
        end
    When name of this page = Event3
        if counter <> "event3" then
            set sysLockScreen to true
            pop sysHistory into LastPage
            go to page "thirdEvent"
            set sysLevel to author
            select page "thirdEvent"
            send copy
            go to LastPage
            set sysLevel to reader
            executeRemote "set sysSuspendMessages to false;" &\
            "set focus to null;send paste;" &\
            "set sysSuspendMessages to true" application toolBook topic
            put "event3" into counter
            send getLesson
        else
            send getLesson
        end
    When name of this page = Event4
        if counter <> "event4" then
            set sysLockScreen to true
            pop sysHistory into LastPage
            go to page "fourthEvent"
            set sysLevel to author
            select page "fourthEvent"
            send copy
            go to LastPage
            set sysLevel to reader
            executeRemote "set sysSuspendMessages to false;" &\
            "set focus to null;send paste;" &\
            "set sysSuspendMessages to true" application toolBook topic
            put "event4" into counter
            send getLesson
        else
            send getLesson
        end
    When name of this page = Event5
        if counter <> "event5" then
```

```
            set sysLockScreen to true
            pop sysHistory into LastPage
            go to page "fifthEvent"
            set sysLevel to author
            select page "fifthEvent"
            send copy
            go to LastPage
            set sysLevel to reader
            executeRemote "set sysSuspendMessages to false;" &\
            "set focus to null;send paste;" &\
            "set sysSuspendMessages to true" application toolBook topic
            put "event5" into counter
            send getLesson
        else
            send getLesson
        end
When name of this page = Event6
        if counter <> "event6" then
            set sysLockScreen to true
            pop sysHistory into LastPage
            go to page "sixthEvent"
            set sysLevel to author
            select page "sixthEvent"
            send copy
            go to LastPage
            set sysLevel to reader
            executeRemote "set sysSuspendMessages to false;" &\
            "set focus to null;send paste;" &\
            "set sysSuspendMessages to true" application toolBook topic
            put "event6" into counter
            send getLesson
        else
            send getLesson
        end
When name of this page = Event8
        if counter <> "event8" then
            set sysLockScreen to true
            pop sysHistory into LastPage
            go to page "eighthEvent"
            set sysLevel to author
            select page "eighthEvent"
            send copy
            go to LastPage
            set sysLevel to reader
            executeRemote "set sysSuspendMessages to false;" &\
            "set focus to null;send paste;" &\
            "set sysSuspendMessages to true" application toolBook topic
            put "event8" into counter
            send getLesson
        else
            send getLesson
        end
When name of this page = Event9
        Request "Do you wish to have a page for event 9 or do you just
        If it = "New Page" then
            set sysLockScreen to true
            pop sysHistory into LastPage
```

```
                    go to page "ninthEvent"
                    set sysLevel to author
                    select page "ninthEvent"
                    send copy
                    go to LastPage
                    set sysLevel to reader
                    executeRemote "set sysSuspendMessages to false;" &\
                    "set focus to null;send paste;" &\
                    "set sysSuspendMessages to true" application toolBook topic
                    send getLesson
                end
                if it = "Go" then
                    send getLesson
                end
        end
        set sysSuspend to true
        --if the lesson was accidentally closed it will run it.
        if "Failed: No server" is in sysError then
            get BookName of this book
            Run it
        END
end

To handle getLesson
    local ThisHandle
    --brings the lesson window to the front of the screen
    set sysSuspend to false
    get bookName of this book
    getRemote "sysWindowhandle" application ToolBook topic it
    put it into ThisHandle
    linkdll "user"
        int BringWindowToTop(word)
    end
    get bringWindowToTop(ThisHandle)
    if "Failed: No server" is in sysError then
        get BookName of this book
        Run it
    END
    set sysSuspend to true
end
```

THE LEADERSHIP EFFECTIVENESS ASSESSMENT PROFILE (LEAP)
SUMMER RESEARCH ACTIVITIES

AMIE HEDLEY-GOODE

ABSTRACT

This paper describes the major tasks assigned to me while on summer internship with the Personnel Assessment Technology Function, Individual Attributes Branch, Manpower & Personnel Division, Armstrong Laboratory, Human Resources Directorate, Brooks Air Force Base. These responsibilities centered around the Leadership Effectiveness Assessment Profile (LEAP) instrument currently under development for the Air Force. The projects included organizing a LEAP Laboratory Advisory Group meeting, identifying and acquiring available criteria to use for LEAP validation, and the development and implementation of peer performance ratings to gather additional criteria for validation.

INTRODUCTION

This paper is written to summarize the activities undertaken on the Leadership Effectiveness Assessment Profile (LEAP) project as a part of my summer internship. Because these summer activities were centered around a large, multifaceted research project of which my activities were only a part, this paper does not follow the normal research paper format. Rather it will be a descriptive paper about the major tasks I undertook through which I contributed significantly to several aspects of the project. The paper will begin with an overview of the LEAP project and its progress up to this summer. Then there will be several sections each devoted to one of the major tasks for which I was responsible. Each section will detail the specific issues underlying the task, how a solution was approached, and finally what outcomes resulted. The paper will end with a general conclusion regarding all the above described activities.

LEAP BACKGROUND

For several years, Air Force scientists have been interested in improving their selection and classification processes by developing new measures to supplement the existing cognitive measures. These existing instruments are quite effective at measuring general cognitive ability and some specific abilities, but LEAP scientists argued that

other non-cognitive attributes should also be measured
(Appel, Grubb, Shermis, Watson, & Cole, 1990; Watson, 1989;
Watson, Elliott, & Appel, 1988). In response to this need,
LEAP development was begun.

The Leadership Effectiveness Assessment Profile (LEAP)
is a biographical data instrument being designed to measure
additional non-cognitive attributes such as leadership and
management potential in Reserve Officer Training Corps
(ROTC) and Air Force Officer Training School (OTS). This
instrument will be used to supplement the existing tests
such as the Air Force Officer Qualifying Test (AFOQT).

The initial development involved determining the
conceptual model of Air Force officer effectiveness and
retention. The constructs of the conceptual model were then
broken down into sub-constructs and finally into behavior
elements from which biodata items were developed. Initial
pilot testing and refining of the biodata instrument was
then conducted.

SUMMER 1991 LEAP ACTIVITIES

During the summer of 1991, the LEAP instrument was to
undergo a more extensive revision and a large pilot testing
to determine if the instrument was approaching a degree of
refinement at which it could be considered for operational
use. There were several tasks to be accomplished by the end
of the summer in order to facilitate this decision regarding

the status of the LEAP. The first task was to acquire some outside expertise to evaluate the instrument and provide advise on improvements. Second, it was necessary to determine what criteria existed for validation purposes and to take the necessary steps to obtain these data. Finally, it was considered advantageous that another criterion measure be developed and administered to obtain peer rating data for validation. These three tasks were my primary responsibilities over the summer. Each will be described in detail on the following pages.

LEAP LABORATORY ADVISORY GROUP (LAG) MEETING

The LEAP instrument had been under development for many months and all involved parties were interested in obtaining some outside critique from experts in the areas of leadership and biodata. These experts would be able to answer such questions as, do the items developed adequately represent the constructs they purport to measure? What were the limitations of using biodata items for personnel selection and classification? What types of data are appropriate for use as criteria for validating the LEAP instrument? What are appropriate criteria for assigning an item to a scale?

In order to gain expert advise on these and many other questions, a Laboratory Advisory Group (LAG) meeting was planned to assess the progress and future direction of the

LEAP. The primary goal of the LAG was to help the Air Force determine if they were on course with the approach taken to develop an instrument to assess leadership and other attributes for officer selection and classification.

A LAG meeting date was set and three outside scientific advisors were invited to come and review the instrument. Other Air Force personnel in positions of particular relevance to this project were also invited to attend. The meeting was held for a day and a half during which time the LEAP Project manager and the subcontractor for the project discussed various facets of this research to date. Following this, discussions were held regarding improvements to the instrument and to present and future research plans. On the morning of the second day, LAG members provided detailed feedback to AL/HRMI management.

Th.s LAG meeting provided a great deal of information regarding the current instrument and possible ways to improve it for future use. Using this advise the LEAP instrument underwent careful revision to prepare it for the summer field testing. Additional items were added and some existing items were reworded. Faking detection items were also added.

Summer field testing should provide the best opportunity to empirically assess the adequacy of the LEAP. Following the summer field testing phase, AL/HRMI plans to

address additi‹ al recommendations made by LAG members.

CRITERIA GATHERING

To validate the LEAP instrument, it is necessary to have criteria against which to make judgements. Prior to the summer of 1991, few criteria were available, and those that were available were difficult ⎽o obtain. Thus a very important aspect of a successful summer field test was to identify and obtain criteria.

The summer field testing was to involve ROTC cadets at five summer encampments. Every ROTC cadet is required to attend one summer encampment for a period of four or six weeks. These field training encampments serve the purpose of training cadets in such areas as leadership, officership, and physical fitness. This training helps develop in-depth knowledge of basic military skills and an appreciation for the military way of life. During these encampments each cadet was required to complete a test and retest of the LEAP instrument.

It was also necessary to search out and obtain the best possible criteria available at these summer encampments. The first st⎽p taken was to contact the ROTC/DOTF and inquire to the availability of any measures at the encampments that could serve as criteria for LEAP validation. Approval was gained from the ROTC/DOTF to obtain any measures that were felt to be useful for

validation. The next step involved interviewing several of the commanding officers at an ROTC summer encampment. Interviews were conducted with the Commander of the entire camp , the Commander of Cadets, the Director of Training, and a Field Training Officer. The information gained from these interviews allowed me to determine that there were several pieces of information that appeared to be useful.

This criterion information being obtained from each summer encampment will allow validation testing to be conducted on the LEAP instrument. One piece of information being obtained is the performance evaluation each cadet receives at the end of the camp. This evaluation is conducted by the field training officer responsible for that cadet's activities throughout the summer camp. Each cadet was given a 1 to 4 point rating on several separate dimensions of performance. The cadet also receives an overall rating which is computed by taking the average of the multiple dimensions. These ratings are based on the training officer's observations of the cadet as well as information provided on peer evaluation sheets. These rating forms serve as the final performance record for a cadet and are kept in his ROTC file permanently.

A form of peer nominations will also be collected. These peer nominations are done after several weeks at the encampments. The cadets are asked to list the top and

bottom five cadets in their groups. They are also required
to list the strengths and weaknesses of these cadets. This
is important information because often the behaviors some
cadets exhibit in front of their commanding officers are not
the same behaviors exhibited when only other cadets are
present.

Additional criterion information will also be provided
concerning which cadets did not successfully complete the
field training and any reasons why. If for example a cadet
left camp early, this information will be provided as well
as if this early departure was voluntary or involuntary.

Each camp presents several awards at the completion of
the field training. The award winners will be collected.
At the end of the camp, the commanders also determine those
cadets who fell into the bottom 25% of those present. This
is done by examining the point totals on the performance
evaluation forms, as well as discussion between the field
training officers. These cadets are those who performed the
most poorly throughout their time at camp. This data is
important because it will give us a way to examine not only
those who performed the best, but also those who were the
poorest performers.

The above mentioned criteria will be used to validate
the LEAP. It will be possible to determine if those
individuals who scored high on leadership potential or other

relevant dimensions on the LEAP instrument actually performed that way at their encampments.

ADDITIONAL CRITERION DEVELOPMENT

LAG members and AL/HRMI staff considered it beneficial to obtain additional criterion data in the form of peer ratings on dimensions specific to the LEAP, as well as on overall performance or success. Several suggested methods were researched and a final decision was made to develop a quantified peer rating form. Pulakos and Borman, 1986 and Stricker, 1989 have used similar peer rating forms to acquire criterion data for validation purposes. Their research was used as a basis to develop the current instrument.

The initial steps required the development of items designed to measure the frequency of certain dimensions of performance. The items were reviewed and revised several times by AL/HRMI staff and the subcontractor. The instrument was also presented to a Field Training Officer from a summer encampment to get his comments and suggestions regarding the items and the ability of the cadets to actually observe the behaviors being measured. The final instrument (See Appendix) contains 19 items, 17 measuring individual dimensions of performance and two measuring overall performance.

The items were responded to on a one to five point

scale measuring the frequency of times a cadet had exhibited the behavior throughout the encampment. Careful consideration was given to the anchors placed on the scale since it is very important to place a frame of reference around the scale points.

Because a rater would be rating several cadets, consideration was given as to how the individuals should respond on the rating form. Should they respond to all 19 items for each cadet, or should they respond one item at a time for all cadets? For example, a rater could read item one and give a response to that item for each ratee he/she is rating, then move on to item two. By responding item by item across ratees the time it would take to complete the instrument could be reduced. This method might also help lessen halo and increase discrimination between ratees. The item by item method of responding was accepted and the forms were designed to facilitate this.

Once the instrument was ready it was necessary to determine to whom it would be administered. Due to the complicated nature of this procedure and the need for a short rater training session, the AL/HRMI LEAP project manager decided that I should administer these ratings in person. To do so at all five bases would have been cost prohibitive. Thus, these peer ratings were administered in person at only two bases, Lackland AFB which is collocated

in San Antonio with the Armstrong Laboratory, and Plattsburg, NY. In addition to cost considerations when selecting these two sights, the number and representativeness of the cadets was also considered. Lackland and Plattsburgh had the largest number of cadets at their encampments, and these cadets were very representative of the larger field testing sample.

Because of the length and the time allowed for testing at the camps, not all cadets could be evaluated. Each camp is broken into six to eight groups or flights. Each flight normally contains 18 to 24 people. Each cadet would have sufficient time to rate eight of his fellow flight members. It was also necessary to have each ratee rated by 10 raters if one hoped to get stable interrater agreement (Kane & Lawler, 1978; Winch & Anderson, 1967). Based on these requirements, each flight was split in half and each half rated eight individuals.

Cadet Ratee Selection

It was necessary to determine which cadets would be rated. This was done by a rather complicated randomization process. First, each flight was randomly split into two groups. From each of these two groups, eight individuals were randomly selected. These two groups of eight where then crossed and matched with the opposite original group of 12. This was necessary so that no one would be given

his/her own name to rate. Every member of the group of 12 was then responsible for rating each of eight cadets. Forms were produced for each individual to tell them the eight cadets they were responsible for rating. In this process the individuals did not know who was rating who or if they themselves were being rated by someone else.

By following this process, 16 individuals in each flight were rated. Each individual was being rated by 10-12 separate raters. In total from the two encampments, this produced peer rating data on approximately 225 cadets.

Peer Rater Training

It was important to gain the most accurate data possible from these peer rating evaluations. In order to do this, a rater training session was designed. Research on rater training has concluded that training is likely to improve performance appraisals (Landy & Farr, 1980; Pulakos & Borman; Zedeck & Cascio, 1982). Other research has demonstrated that rating errors such as leniency and halo can be reduced by appropriate training (Borman, 1975, 1979; Brown, 1968; Latham, Wexley, & Pursell, 1975). It may also be possible to enhance rater accuracy by providing raters with training (McIntyre, Smith, & Hassett, 1984). This project's rater training consisted of four parts each of which will be described below.

Project Overview. The first part of the training was

designed to acquaint raters with the LEAP project. Even though these cadets had taken the LEAP, they had not up to this point, had direct contact with any personnel from the Air Force who were working on the LEAP development. The cadets were given an explanation on how the LEAP was to be used to assist in the selection and classification of Air Force officers. They were also told about the summer field testing of the LEAP and given an explanation regarding the definition and the importance of the validation process. Their important role in this validation process was also stressed.

Peer Rating Instrument. The second part of the training involved making the cadets familiar with the peer rating form. First it was explained how this instrument would be used to examine if the LEAP instrument was performing as we expected it to. Next they were assured that the data were for research purposes only and that the information would not affect them or those they were rating in any way. A careful explanation of the instrument was then given. One of the items was used as an example to explain how to use the scale to make relatively objective performance ratings. The cadets were instructed on how they would be rating the cadets item by item. They were told to read an item, get the performance behavior in their mind and then respond with a rating for each of the cadets on their

list. They then were to move on to the next item and follow
the same procedure.

An explanation was then given regarding the information
on the peer rating list each cadet had received. These peer
rating lists contained the names of the eight cadets to be
rated. A short explanation of how these ratees were
determined was given and a double check was made to be sure
no one was assigned to rate themselves.

Rater Error Training. A short training section was
given regarding four common rater errors -- halo, leniency,
critical incident bias, stereotyping bias. Halo was
explained and examples were given. Raters were encouraged
to discriminate between performance behaviors for each
cadet. Raters were also urged to use the whole scale when
making these ratings and to not be concerned that their
ratings would hurt or help their fellow cadets. At this
point it was again stressed that these ratings were for
research only and would not directly affect the rated
cadets. Critical incident bias and stereotyping bias were
also explained and it was stressed that raters try to use
the entire time period they had been at the encampment to
make their ratings. They were also encouraged not to let
other factors besides performance influence their ratings.
Finally, and most importantly the raters were encouraged to
be as accurate as possible and take their time to make the

best judgements they could.

Scantron Forms. The last portion of the training involved looking over the scantron answer forms and filling in some special codes. This was necessary because without the proper coding on the answer forms the data would be unusable. Raters were carefully instructed to fill in the codes that signified the flight and group of their ratees. This information was very clearly provided on the peer rating lists, but by doing this step together it was more assured that the codes would be properly filled in on the answer sheets. Because each cadet was using two answer sheets, it was also necessary for them to code their sheets one and two. Finally, all cadets were asked to code their social security numbers on both of their answer sheets. It was explained to them that this was necessary to be sure their two answer sheets would be kept together. Overhead transparencies were used to facilitate this process.

Rater Training Program Summary

This rater training program had several important features. First, it was kept relatively short (approximately 20 minutes). This was necessary because of the time limits and also to increase the likelihood of keeping the attention of the cadets. Second, all of the information provided was simplified so it could be easily understood. Third, it provided the cadets with important

background information to help them realize the importance of their participation. It also stressed to them the confidentiality and research-only purposes. Finally, it provided them with clear direction and example regarding how to use the scales to respond to the items.

The cadets appeared interested and satisfied with the training sessions. The training did cause various questions to be raised which in turn helped clarify issues of concern to the cadets. No formal analyses were done on the training program, however, it was felt that it was a necessary and worthwhile use of the cadets' time to foster the most accurate ratings possible.

Following the rater training session, the cadets then completed the peer ratings. The time required for the cadets to complete the ratings was between 30-40 minutes.

PEER PERFORMANCE RESULTS

The peer rating data collected by the investigator can be used as an additional criterion for LEAP validation. However, at the time of this report the validation analyses have not yet started so no results can be reported.

CONCLUSION

In concluding this paper, it is necessary to summarize the main activities undertaken by this author over the last three months. First, a LEAP Laboratory Advisory Group was instigated and a successful LAG was held. Second, a search

was undertaken to identify and gain access to available criteria for LEAP validation. Several pieces of important criteria have been identified and are presently being gathered by ROTC personnel to be forwarded on to the researchers involved in LEAP validation. Finally, a peer rating instrument was developed and implemented to gain additional criterion data for validation purposes. In addition to these tasks, I also assisted in the revision of the LEAP instrument before summer pilot testing and coordinated this summer pilot testing at the various ROTC summer encampments around the Country.

This summer work was very valuable in assisting the Air Force scientists to continue the progress on the LEAP instrument. The information gained from the summer will allow the researchers to move the LEAP closer to a final form that will be ready for actual implementation and use.

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AFROTC PEER RATING FORM

DIRECTIONS: Rate each of the 8 randomly selected cadets listed on your Peer Rating List using the "Almost Never" to "Almost Always" scale below to indicate the frequency of times you observed their behaviors on each of the 19 dimensions listed on the pages which follow. If you do not have enough information concerning a particular behavior for a certain cadet, please mark the "F" response.

A-----------------B-------------------C-----------------D------------E   F

Almost	Infrequently	Sometimes	Frequently	Almost	Not
Never				Always	Enough
					Information

RECORD EACH OF YOUR RATINGS ON THE MACHINE SCORABLE ANSWER SHEETS. Mark your answer on the appropriate line number (as given on this form) and in the space corresponding to the A to E rating you've selected. Do this for each dimension and for each cadet rated. You will be rating all 8 cadets on a given dimension before going on to the next dimension.

YOU SHOULD NOT IDENTIFY YOURSELF ON THE ANSWER SHEET.

However, so that is possible to identify who you are rating, in the section called, "Special Codes," under Column K, enter the number of your FLIGHT as indicated on your PEER RATING LIST. Under Column L, enter the number of the GROUP to which your rated cadets belong (1 or 2), as indicated on the top of your Peer Rating List.

A----------------B----------------C----------------D----------------E   F

Almost   **Infrequently**   **Sometimes**   **Frequently**   **Almost**   **Not**
Never   **Always**   **Enough**
                                                                                              Information

DIMENSION 1: When serving as the leader, this cadet motivated others to go beyond their best previous levels of performance.

1. First Cadet on your List
2. Second Cadet on your List
3. Third Cadet on your List
4. Fourth Cadet on your List
5. Fifth Cadet on your List
6. Sixth Cadet on your List
7. Seventh Cadet on your List
8. Eighth Cadet on your List

DIMENSION 2: When serving as the leader, this cadet rewarded good performance and reprimanded poor performance of others.

9. First Cadet on your List
10. Second Cadet on your List
11. Third Cadet on your List
12. Fourth Cadet on your List
13. Fifth Cadet on your List
14. Sixth Cadet on your List
15. Seventh Cadet on your List
16. Eighth Cadet on your List

DIMENSION 3: This cadet was able to identify problems, analyze them, and then come up with effective solutions.

17. First Cadet on your List
18. Second Cadet on your List
19. Third Cadet on your List
20. Fourth Cadet on your List
21. Fifth Cadet on your List
22. Sixth Cadet on your List
23. Seventh Cadet on your List
24. Eighth Cadet on your List

CONTINUE USING THE FOLLOWING SCALE TO INDICATE THE FREQUENCY OF BEHAVIOR FOR EACH CADET ON THE FOLLOWING DIMENSIONS. IF YOU DON'T HAVE ENOUGH INFORMATION ON A CADET FOR A PARTICULAR DIMENSION, MARK RESPONSE "F".

A----------------B--------------------C------------------D--------------E   F

Almost   Infrequently   Sometimes   Frequently   Almost   Not
Never   Always   Enough
                                                                                             Information

DIMENSION 4: By monitoring what was going on, this cadet gathered useful information, then shared it with others so that it could be used to help the flight better carry out its work.

25. First Cadet on your List
26. Second Cadet on your List
27. Third Cadet on your List
28. Fourth Cadet on your List
29. Fifth Cadet on your List
30. Sixth Cadet on your List
31. Seventh Cadet on your List
32. Eighth Cadet on your List

DIMENSION 5: This cadet worked well with other flight members, drawing on each cadet's ideas, strengths or resources to collaboratively achieve the group's goals.

33. First Cadet on your List
34. Second Cadet on your List
35. Third Cadet on your List
36. Fourth Cadet on your List
37. Fifth Cadet on your List
38. Sixth Cadet on your List
39. Seventh Cadet on your List
40. Eighth Cadet on your List

CONTINUE USING THE FOLLOWING SCALE TO INDICATE THE FREQUENCY OF BEHAVIOR FOR EACH CADET ON THE FOLLOWING DIMENSIONS. IF YOU DON'T HAVE ENOUGH INFORMATION ON A CADET FOR A PARTICULAR DIMENSION, MARK RESPONSE "F".

A------------------B--------------------C------------------D------------E   F

| Almost Never | Infrequently | Sometimes | Frequently | Almost Always | Not Enough Information |

DIMENSION 6: This cadet worked effectively on his or her own, relying on his or her own judgment to make needed decisions.

41. First Cadet on your List
42. Second Cadet on your List
43. Third Cadet on your List
44. Fourth Cadet on your List
45. Fifth Cadet on your List
46. Sixth Cadet on your List
47. Seventh Cadet on your List
48. Eighth Cadet on your List

DIMENSION 7: This cadet showed a concern for maintaining good health through willing participation in more than the required physical conditioning.

49. First Cadet on your List
50. Second Cadet on your List
51. Third Cadet on your List
52. Fourth Cadet on your List
53. Fifth Cadet on your List
54. Sixth Cadet on your List
55. Seventh Cadet on your List
56. Eighth Cadet on your List

CONTINUE USING THE FOLLOWING SCALE TO INDICATE THE FREQUENCY OF BEHAVIOR FOR EACH CADET ON THE FOLLOWING DIMENSIONS. IF YOU DON'T HAVE ENOUGH INFORMATION ON A CADET FOR A PARTICULAR DIMENSION, MARK RESPONSE "F".

A----------------B--------------------C------------------D--------------E   F

Almost   Infrequently   Sometimes   Frequently   Almost   Not
Never   Always   Enough
                                                                            Information

DIMENSION 8: This cadet willingly made personal sacrifices out of loyalty to the Air Force or out of commitment to its goals and values.

57. First Cadet on your List
58. Second Cadet on your List
59. Third Cadet on your List
60. Fourth Cadet on your List **(TURN ANSWER SHEET TO SIDE 2 AND CONTINUE)**
61. Fifth Cadet on your List
62. Sixth Cadet on your List
63. Seventh Cadet on your List
64. Eighth Cadet on your List

DIMENSION 9: This cadet worked hard on assigned duties and tasks, and was not satisfied until the best possible performance was achieved.

65. First Cadet on your List
66. Second Cadet on your List
67. Third Cadet on your List
68. Fourth Cadet on your List
69. Fifth Cadet on your List
70. Sixth Cadet on your List
71. Seventh Cadet on your List
72. Eighth Cadet on your List

CONTINUE USING THE FOLLOWING SCALE TO INDICATE THE FREQUENCY OF
BEHAVIOR FOR EACH CADET ON THE FOLLOWING DIMENSIONS. IF YOU
DON'T HAVE ENOUGH INFORMATION ON A CADET FOR A PARTICULAR
DIMENSION, MARK RESPONSE "F".

A-----------------B------------------C------------------D------------E   F

Almost	Infrequently	Sometimes	Frequently	Almost	Not
Never				Always	Enough
					Information

DIMENSION 10. This cadet worked hard at all duties or tasks despite any adversity or
frustration experienced.

73. First Cadet on your List
74. Second Cadet on your List
75. Third Cadet on your List
76. Fourth Cadet on your List
77. Fifth Cadet on your List
78. Sixth Cadet on your List
79. Seventh Cadet on your List
80. Eighth Cadet on your List

DIMENSION 11: This cadet listened to, advised and supported others.

81. First Cadet on your List
82. Second Cadet on your List
83. Third Cadet on your List
84. Fourth cadet on your List
85. Fifth Cadet on your List
86. Sixth Cadet on your List
87. Seventh Cadet on your List
88. Eighth Cadet on your List

CONTINUE USING THE FOLLOWING SCALE TO INDICATE THE FREQUENCY OF BEHAVIOR FOR EACH CADET ON THE FOLLOWING DIMENSIONS. IF YOU DON'T HAVE ENOUGH INFORMATION ON A CADET FOR A PARTICULAR DIMENSION, MARK RESPONSE "F".

A------------------B------------------C------------------D------------E   F

Almost   Infrequently   Sometimes   Frequently   Almost   Not
Never   Always   Enough
                                                                       Information

DIMENSION 12. This cadet encouraged others to take the work of the flight more seriously, and to make a stronger commitment to the achievement of its goals.

89. First Cadet on your List
90. Second Cadet on your List
91. Third Cadet on your List
92. Fourth Cadet on your List
93. Fifth Cadet on your List
94. Sixth Cadet on your List
95. Seventh Cadet on your List
96. Eighth Cadet on your List

DIMENSION 13: This cadet inspired others and gained their support for his/her suggestions and ideas.

97. First Cadet on your List
98. Second Cadet on your List
99. Third Cadet on your List
100. Fourth Cadet on your List
101. Fifth Cadet on your List
102. Sixth Cadet on your List
103. Seventh Cadet on your List
104. Eighth Cadet on your List

CONTINUE USING THE FOLLOWING SCALE TO INDICATE THE FREQUENCY OF
BEHAVIOR FOR EACH CADET ON THE FOLLOWING DIMENSIONS. IF YOU
DON'T HAVE ENOUGH INFORMATION ON A CADET FOR A PARTICULAR
DIMENSION, MARK RESPONSE "F".

A----------------B----------------C----------------D----------E   F

Almost   Infrequently   Sometimes   Frequently   Almost   Not
Never   Always   Enough
                                                                   Information

DIMENSION 14: This cadet found new and creative ways to solve problems or complete tasks.

   105. First Cadet on your List
   106. Second Cadet on your List
   107. Third Cadet on your List
   108. Fourth Cadet on your List
   109. Fifth Cadet on your List
   110. Sixth Cadet on your List
   111. Seventh Cadet on your List
   112. Eighth Cadet on your List

DIMENSION 15: In a leadership position, he/she considered the needs and abilities of others when assigning tasks or duties.

   113. First Cadet on your List
   114. Second Cadet on your List
   115. Third Cadet on your List
   116. Fourth Cadet on your List
   117. Fifth Cadet on your List
   118. Sixth Cadet on your List
   119. Seventh Cadet on your List
   120. Eighth Cadet on your List

CONTINUE USING THE FOLLOWING SCALE TO INDICATE THE FREQUENCY OF BEHAVIOR FOR EACH CADET ON THE FOLLOWING DIMENSIONS. IF YOU DON'T HAVE ENOUGH INFORMATION ON A CADET FOR A PARTICULAR DIMENSION, MARK RESPONSE "F".

A----------------B--------------------C------------------D--------------E   F

Almost	Infrequently	Sometimes	Frequently	Almost	Not
Never				Always	Enough
					Information

DIMENSION 16: This cadet motivated others to act by raising challenging problems or questions for them to solve. This cadet helped others find new ways to think and to handle tasks or assignments.

1. First Cadet on your List
2. Second Cadet on your List
3. Third Cadet on your List
4. Fourth Cadet on your List
5. Fifth Cadet on your List
6. Sixth Cadet on your List
7. Seventh Cadet on your List
8. Eighth Cadet on your List

DIMENSION 17: This cadet planned and carried out activities in an organized fashion.

9. First Cadet on your List
10. Second Cadet on your List
11. Third Cadet on your List
12. Fourth Cadet on your List
13. Fifth Cadet on your List
14. Sixth Cadet on your List
15. Seventh Cadet on your List
16. Eighth Cadet on your List

CONTINUE USING THE FOLLOWING SCALE TO INDICATE THE FREQUENCY OF
BEHAVIOR FOR EACH CADET ON THE FOLLOWING DIMENSIONS. IF YOU
DON'T HAVE ENOUGH INFORMATION ON A CADET FOR A PARTICULAR
DIMENSION, MARK RESPONSE "F".

A------------------B--------------------C------------------D--------------E   F

Almost   Infrequently   Sometimes   Frequently   Almost   Not
Never   Always   Enough
                                                                    Information

DIMENSION 18: This cadet demonstrated qualities that resulted in a high degree of success
during this encampment.

17. First Cadet on your List
18. Second Cadet on your List
19. Third Cadet on your List
20. Fourth Cadet on your List
21. Fifth Cadet on your List
22. Sixth Cadet on your List
23. Seventh Cadet on your List
24. Eighth Cadet on your List

DIMENSION 19: This cadet demonstrated qualities that show the potential to be an outstanding
future Air Force officer.

25. First Cadet on your List
26. Second Cadet on your List
27. Third Cadet on your List
28. Fourth Cadet on your List
29. Fifth Cadet on your List
30. Sixth Cadet on your List
31. Seventh Cadet on your List
32. Eighth Cadet on your List

The Relationship Between Working Memory Capacity and Context Effects in Lexical Access

David J. Hess

The research project that was initiated during the Summer Research Program had two separate goals. First, I wanted to build upon the growing literature that has established the central role of working memory in higher level language processing. In two studies addressing context effects in lexical access, I will be examining how individual differences in working memory capacity affect the ability to use prior context to facilitate lexical access. The first study, a replication of Hess & Foss (1991) with the Air Force population, will look at how working memory capacity affects the use of global and local information in a naming task. I anticipate that performance of recruits with larger working memory capacities will replicate the Hess & Foss findings, which were based on college students. However, I predict that recruits with smaller working memory capacities will be less able to make use of global information and will rely more heavily on local information. The second study is similar to the first, but uses a standard memory load technique to manipulate effective working memory capacity. I predict that because the memory load will reduce effective memory capacity both large and small working memory capacity recruits will be less able to take advantage of the global information.

The second goal of the summer research project was to begin exploring the components of the working memory system. To this point there are no "pure" measures of articulatory loop capacity. In the third study I constructed a number of articulatory loop tasks which have minimal processing demands and thus are considered to be "purer" measures of the articulatory loop. I expect performance on these tasks to be highly intercorrelated and to define a single articulatory loop factor. This project has the eventual goal of explicitly defining the properties of the articulatory loop and the central executive and determining how the properties of these components relate to various aspects of comprehension.

In the past decade, determining the relationship between working memory capacity and various aspects of language comprehension has become very popular. Basically, there have been two different conceptions of the working memory system with regard to its relationship to comprehension. The first of these, proposed by Baddeley (1986), views working memory as a general system consisting of two slave systems, the articulatory loop and the visuo-spatial sketchpad, and a control system known as the central executive. The articulatory loop is a speech based system that is able to retain information for approximately two seconds without rehearsal. With rehearsal the articulatory loop can hold information indefinitely. The articulatory loop is a peripheral system that doesn't have any higher level processing capabilities, but acts as a holding place until its contents can be processed by the central executive. The other slave system, the visuo-spatial sketchpad, does not play a very active role in language comprehension and will not be discussed here (see Baddeley, 1986 for more information). While a limited amount of storage capacity is ascribed to the central executive, its primary function is the control of the working memory system. As Baddeley (p.225, 1986) describes it, the central executive is a "...supervisor or scheduler, capable of selecting strategies and integrating information from several different sources.". Since the central executive component runs the working memory system, it is the most likely candidate to play a role in language comprehension. Given this fact, surprisingly little research has been done (Baddeley, Logie, Nimmo-Smith, & Brereton, 1985; Turner & Engle, 1989) that establishes a relationship between the central executive and comprehension. One possible reason for this lack of empirical evidence for such a relationship is that the central executive is so ill defined, as Baddeley himself admits (personal communication, 1991). Thus the problem isn't only to establish a correspondence between the central executive and aspects of comprehension, but also to find a suitable measure of the executive's capacity and processing efficiency. Baddeley

(1986) has suggested that measures of the central executive should involve simultaneous processing and storage. Though this definition for an executive measure has lead to some success, it leaves open the possibility that individuals may differ on various information processing dimensions ascribed to the executive.

A second approach to relating working memory and comprehension has postulated a special working memory for language (along with the potential for working memories in other domains) (Daneman & Carpenter, 1980, 1983; Just & Carpenter. 1991). According to the Carnegie-Mellon (CMU) group, working memory is viewed as a workspace. Within this workspace both storage and processing is carried out. As a result of this, various models by this group have claimed that individuals may differ either on their storage capacity or their processing efficiency. The CMU group has suggested that since the working memory system is language specific, any measure designed to demonstrate a relationship between working memory and language comprehension must engage the processes involved in language comprehension and involve processing and storage.

A number of researchers have demonstrated the impact of working memory capacity on various aspects of comprehension including, performance on standardized comprehension measures (Baddeley, Logie. Nimmo-Smith, & Brereton, 1985; Daneman & Carpenter, 1980,1983; Masson & Miller, 1983), ability to resolve lexical and syntactic ambiguity (Daneman & Carpenter, 1983: MacDonald. Carpenter. & Just. 1990), and children's ability to draw inferences (Oakhill. 1984). to name a few. Some important models of text comprehension (e.g. Kintsch & van Dijk. 1978; van Dijk & Kintsch. 1983) have also recognized the central role that working memory plays in the construction of a coherent mental representation of discourse. Thus. working memory plays a large part in many of the higher level processes involved in language comprehension.

Given that working memory has a significant role in higher level language comprehension, the primary goal of my research is to identify specific comprehension processes that are influenced by working memory. The experiments I am conducting will investigate both lexical encoding and inferential processes underlying the construction of a coherent discourse model. In addition, this research program addresses how individual differences in working memory capacity affect the ability to make use of the information in the discourse model to integrate new information. The vast majority of the studies that have associated working memory and language comprehension have relied on restricted samples, typically composed of college students. Based on the fact that working memory is a powerful source of individual differences in cognitive functioning, access to a population with a broader range of abilities allows us to examine the scope of working memory's impact on cognitive functioning. The Air Force population is already known to vary considerably in cognitive abil___, and thus provides an opportunity to test cognitive models of individual differences.

The studies presented here examine .ow working memory capacity influences the use of context in lexical access. The motivation behind linking working memory and contextual influences on lexical access is that working memory capacity provides measurable constraints of the information processing system. These constraints presumably affect the real time operation of comprehenders and thus allow us to observe breakdowns in the information processing system. When the system breaks down and what mechanisms are affected can potentially shed some light on the processes involved in language comprehension in general, and on context effects in lexical access in particular.

One common finding in the study of lexical access is that when a word is preceded by a related context it will be processed faster than when preceded by an unrelated context (e.g. Duffy, Henderson, & Morris, 1989, Hess & Foss, 1991,

Schwanenflugel & Shoben, 1985; Stanovich & West, 1983). For example the word "money" would be processed faster in the sentence "The banker saved the money" than in the sentence "The lifeguard saved the money". Theoretical accounts for this context effect can be categorized into two different classes, depending on their proposed locus of the effect (Foss, 1982). According to the first class of models, the locus of the effect is the lexicon and it is due to intralexical spreading activation. These models have their roots in findings from the semantic memory literature (e.g. Meyer & Schvaneveldt, 1976) of priming for associatively related words when presented in isolation. These models have a number of common characteristics (first outlined by Foss, 1982). First, when a word is preceded by a semantically related word (i.e. doctor-nurse), the second word will be processed faster than if the second word is preceded by a more neutral word (i.e. butter-nurse). Second, the process is automatic, such that when the word "doctor" precedes "nurse", "nurse" will be processed faster regardless of the overall discourse context. Third, the longer the delay or the more links traversed in the semantic network, the less activation is maintained or spread, respectively.

Findings from studies (Foss, 1982; O'Seaghdha, 1989; Simpson, Peterson, Casteel, & Burgess, 1989) that have compared the time course of facilitation effects in sentences to those in lists of words have cast doubt on a simple lexical-lexical spreading activation account. The basic design of these studies is to present sentences that contain associatively related words or to present the same words in a scrambled order, while maintaining the number of intervening words between the associatively related items. One common finding from this research is that priming is observed for targets in the sentence condition over long distances (across many intervening words), but priming is only obtained in the scrambled condition when the associatively related words are adjacent to one another. Duffy et. al. (1989) however, have modified the simple intralexical spreading activation model in order

to account for such results. Specifically, they claim that as a result of ongoing syntactic and integrative processes, the content words in sentences are maintained in a buffer and continue to prime associates over longer distances than lists. Unrelated to the "sentence-list" studies, Duffy et. al. have made another modification to the simple lexical-lexical account whereby it is possible for the combination of words to prime a later target word when not one single word is highly associatively related to the target.

An alternative approach to explaining the context effect is taken by those models that posit the discourse model as the locus. There are two distinct classes of discourse model accounts which have been proposed; those that invoke top-down priming (i.e. Auble & Franks, 1983; Sharkey & Sharkey, 1987) and those that postulate facilitated integration (i.e. Foss & Speer, 1990). In general, both classes of discourse model accounts propose that when a word or phrase is processed, it contacts related structures (i.e. schemas, propositions) in long term memory. Once these related structures are found, the current information and the stored information are amalgamated to form a coherent mental representation of the ongoing discourse. Once a coherent discourse model has been constructed, these two classes of discourse model accounts take different approaches in explaining how the facilitation of related words occurs. According to the top-down priming account, the activation level of lexical items related to the current focus of the discourse model will be raised. Once one of these items is encountered it will be processed faster because it will need less activation to raise it above threshold. On the other hand the facilitated integration account does not postulate pre-access raising of activation. Rather, when a lexical item is related to the discourse, its processing will be facilitated either because its semantic features fit well with the current focus of the discourse model or some aspect related to the lexical item may already be in the discourse model and therefore the item will be integrated faster. I

will discuss specific instantiations of both the top-down and facilitated integration views after presenting recent results from Hess & Foss (1991).

In an attempt to resolve the issue of the locus of the context effect, we conducted a series of experiments in which we presented subjects with a number of short spoken passages. Rather than hearing the last word of each passage, subjects saw it on a computer monitor. We collected the subject's naming latencies to the target words (the last word of each passage). Two aspects of the experimental passages were manipulated (for examples see Table 1). First, we manipulated whether the overall topic of the passage, what we call the global context, was related or unrelated to the target word. Also, we manipulated whether the final phrase of each passage, what we call the local context, contained words that were associatively related or associatively unrelated to the final word. For instance, in the examples in Table 1, the global context is related to the target word "money" when the topic is about money related issues (e.g. buying a car). On the other hand, the global context is unrelated to "money" when the topic is about being at the beach. In the case of the local context, when the final phrase contains the words "the banker saved the", the local context is related to the target word. However, when the final phrase is "the lifeguard saved the", the local context is unrelated to the target. In the experiment of current interest we included a nonsemantic neutral control condition (see Table 1) in order to establish a baseline. According to an intralexical spreading activation view, naming times should be facilitated relative to the control whenever the local context is related to the target regardless of the global context. A discourse model view predicts that naming times will be facilitated relative to the control when the global context is related to the target regardless of the local context.

Our findings supported a discourse model view in that naming latencies for both the global related conditions were facilitated relative to the control. In addition, the two global related conditions did not differ from one another. The strongest

evidence against the intralexical spreading activation view is that naming latencies in the global unrelated - local related condition did not differ from the control. Such findings call into question the notion that associative priming is an automatic process since the priming effects obtained seem to be dependent on the overall topic of the discourse, not the presence of associatively related words nearby the target word.

Presently we have three competing models which are able to account for the Hess & Foss findings. The first model, which we call the Lexical Reinterpretation Model (LRM), was first proposed by Foss (Foss & Ross, 1983; Foss & Speer, 1990), and is a member of the class of facilitated integration models. In order to account for context effects, and the lack of an associative priming effect, Foss makes an appeal to semantic flexibility theories (Barsalou, 1982; Greenspan, 1986). According to the LRM, on the first occurrence of a word both its context independent (CI) and context dependent (CD) properties are activated. Once the word has been integrated into the discourse model only those properties of the word that are relevant to the current focus of the discourse will be instantiated. As long as the same topic has been maintained, subsequent access of the word will be made from the discourse model. As a result only the word's CD properties will be activated. Thus in the example passage in which the lifeguard wants to buy a car, lifeguard related concepts will be activated on its first occurrence. Once lifeguard is integrated into the discourse model only those concepts related to consumer concerned about finances will be instantiated, not everything related to lifeguards in general (e.g. the beach, swimming, etc). When lifeguard comes up for the second time notice that according to the LRM only those concepts that are contextually related will be activated, and therefore no associative priming effect is obtained.

Our second and third models appeal to top-down priming as the source of the facilitation effect. At present we have two potential variations of a top-down priming

account. According to the first variation, which I will call Discourse Activation Modulation (DAM), concepts in the lexicon that are related to the current focus or topic will receive feedback from the discourse model. As a result of this feedback, the activation levels of these related concepts will be raised and therefore the processing of these items will be facilitated. Another function of the discourse model in the DAM model is to suppress concepts unrelated to the current topic. These two ideas, those of raising and suppressing activation levels, are conceptually similar to the mechanisms of suppression and enhancement proposed by Gernsbacher (1990). The DAM model would account for the lack of associative priming effect in the Hess & Foss study by the fact that when words are unrelated the current focus their activation levels will be suppressed.

Our second version of the top-down priming approach, which I will call Discourse Model Building (DMB), makes a number of unique claims. DMB views the process of comprehension as one of recruiting as much information as may be relevant in order to build a coherent discourse model. According to DMB when a word is encountered early in a passage, prior to a topic having been firmly established, the discourse model attempts to incorporate as much information as possible that is related to that word in order to establish or define the topic. However, once the focus of the current topic has been firmly established, only information that is related to the topic will be incorporated into the discourse model. One can view the discourse model as having a broad scope of facilitation when the topic has not been well defined or established. By the same token, once the topic has been well defined the discourse model has a narrow scope of facilitation. Thus, according to DMB, simple associative effects are inoperative during discourse processing. In fact, DMB views simple word list priming effects as the degenerate case of an attempt to build a coherent discourse representation by activating broadly related information. Notice that this model has the advantage of not having to

postulate a suppression mechanism because it denies the existence of automatic spreading activation in discourse processing. The denial of an automatic spreading activation mechanism however, is one aspect of this model that has yet to be empirically tested.

Study 1

Given the goal of demonstrating a relationship between working memory capacity and lexical access I decided to partially replicate the Hess & Foss study. Context effects have already been demonstrated using the Hess and Foss materials with a college population. Use of these materials has the dual advantage of providing stimuli that are known to be effective and of allowing us to test the sensitivity of the Air Force Human Resource Lab (AFHRL) hardware and software.

In order to assess the relationship between working memory capacity and lexical access, I included three working memory measures, a variant of the reading span test, letter span, and alphabet recoding. Considering the disagreement about the status of the working memory system (domain independent vs. language specific,. I decided to include tasks that were representative of both points of view. In this version of the reading span task, subjects see a word prior to each sentence which they must retain. The subjects second task is to read each sentence in the set and make a true-false judgment about the sentence. After the last sentence in each set subjects must recall the words that were presented before each sentence. The sentences used in this version of the reading span are relatively simple general knowledge questions. The reading span task is most often associated with those researchers who propose a language specific working memory.

The other working memory measures, alphabet recoding and letter span. are associated with the domain independent view of working memory. The alphabet

recoding task, adapted from Kyllonen & Christal (1990), has the attribute of involving both processing and storage yet does not engage the processes involved in comprehension. Briefly, in this task subjects are presented with a set of letters, ranging in size from one to three letters, one letter at a time. After the presentation of the letters the subject receives an operator and an addend which determine the operation to perform (either successor or predecessor) and the number of transformations (ranging from zero to three). For example if the subject sees "F B J +2" the correct response would be "RDL". This task was considered to tap central executive efficiency as well as contain an articulatory loop component.

In contrast, letter span task only involves storage. In the letter span task subjects are presented with a set of letters that they must remember. The sets range in size from 3,5,7, or 9 letters per set. After all of the letters in a set have been presented a set of test letters is presented, one letter at a time. The subject must decide whether each letter is old or new. For instance, the subject must decide if the first test letter presented was the first letter in the learned set, the second test letter the second in the learned set, and so on. The letter span task was presumed to measure the articulatory loop as well as have a small central executive component. There were two motivations for including the letter span task in the experiment one theoretical and one empirical. The theoretical motivation for the letter span's inclusion was to ascertain the level of independence of the central executive and the articulatory loop. Most likely there will be a good relationship between the central executive and the articulatory loop, such that the majority of subjects who perform well on the executive task will also perform well on the loop task (and vice versa). However it is also possible that there will be those people that perform well on the executive task and poorly on the loop task (and vice versa).

The second motivation for using the letter span task has a more empirical oasis. Given the fact the the articulatory loop isn't considered to play a large role in

comprehension, and assuming the alphabet recoding task contains an articulatory loop component, it would be desirable to partial out the variance associated with the articulatory loop. Thus, in order to obtain a better measure of the central executive, letter span performance will be partialed out of the alphabet recoding score.

If working memory capacity does play a role in determining the magnitude of the context effect then we would expect that both performance on the reading span task and the alphabet recoding task (with the letter span partialed out) to be related to performance on the Hess & Foss experiment. More specifically, those subjects that perform better on the working memory measures should show the same pattern of performance on the Hess & Foss experiment as was found previously with University of Texas undergraduates. On the other hand, I would predict that those subjects that perform poorly on the working memory measures should show a different pattern of results than has been found previously. I would expect that for those subjects with smaller or less efficient working memories there would be an associative priming effect where we hadn't found one previously (the global unrelated - local related condition, Table 1). This finding would be expected on a number of different accounts. First of all, if a subject has a smaller working memory capacity he/she does not have the space or resources to construct as coherent or detailed discourse representation as does someone with a larger working memory capacity. As a result of this less detailed representation, subjects with smaller working memory capacities are less able to use the current topic to generate expectancies or to quickly incorporate incoming words.

A related proposal by Just & Carpenter (1991) suggests that interactive processing in the language processing system consumes working memory resources. Because those people with smaller working memories have limited resources, Just & Carpenter suggest that they are not able to make use of higher level representations to guide lower level processing. Thus, according to this

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account, those subjects with larger working memories would be able to make use of the topic of the discourse model to facilitate the processes of lexical access because they have the resources to do so. However, those subjects with smaller working memories would not be able to use the topic of the discourse model to guide lexical processing because the interactive processes would consume too much of their limited resources.

I have also included two measures of comprehension ability; one a more traditional measure of reading ability (developed by Dr. William Tirre of AFHRL), and the other a measure of ability to suppress inappropriate meanings of ambiguous words (developed by Gernsbacher, Varner, & Faust, 1990). The Tirre Comprehension Test (TCT) was included to examine the relationship between working memory capacity and comprehension ability (as measured by the TCT), as well as that between performance on the TCT and the Hess & Foss experiment.

The purpose of the first comparison (WM-TCT) is to simply replicate past research (Baddeley, Logie, Nimmo-Smith, & Brereton, 1985; Daneman & Carpenter, 1980,1983; Masson & Miller, 1983) that has found a significant correlation between working memory capacity and comprehension ability. The second comparison, that between the TCT and Hess & Foss, allows us to examine performance on the Hess & Foss experiment in terms of good and poor comprehenders as opposed to large and small working memory capacity. The possibility of there being a different pattern of results in the Hess & Foss experiment when analyzed in terms of comprehension ability compared to when analyzed in terms of working memory capacity is a potentially interesting finding.

Gernsbacher et. al.'s (1990) suppression task was included in order to preliminarily address some of the issues related to our three models (LCM, DAM, DMB) that account for the context effect. The task involves presenting subjects with sentences that end with an ambiguous word or a word semantically related to the

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ambiguous word (e.g. The spy sold the arms or The spy sold the guns). After reading the sentence, subjects see a word that is either related to the contextually relevant sense of the ambiguous word (e.g. rifle) or related to the contextually inappropriate sense (e.g. hand). The latency between the last word of the sentence and the test word is either 100 or 850 msec. The subject's task is to decide whether the test word is related or unrelated to the sentence. Gernsbacher et. al. have found that at the short interval, both skilled and less skilled comprehenders take significantly longer to reject the test word related to the contextually inappropriate sense of the ambiguous word (hand in the example) when the sentence ends in an ambiguous word (arms), relative to when the sentence ends in an unambiguous word (guns). At the long interval, the less skilled comprehenders show the same pattern of results. On the other hand, for the more skilled comprehenders at the long interval there is no difference in the time to reject the contextually inappropriate sense, regardless of the sentence final word. Gernsbacher et. al. have claimed that less skilled comprehenders have inefficient suppression mechanisms and therefore aren't able to suppress the contextually inappropriate sense of the ambiguous words as quickly as the more skilled comprehenders. If we look at performance on the suppression task as an index of ability to use prior information effectively (either by suppressing concepts not related to the current focus or being able to quickly contextualize incoming words) then we would expect those subjects who perform poorly on the suppression task to show associative priming effects. By the same token, those subjects who perform well on the suppression task would not be expected to show an associative priming effect, which would be a replication of earlier findings.

Study 2

The second study attempts to further examine the relationship between working memory capacity and lexical access. In this study, the only modification was to the Hess & Foss experiment which now included a concurrent memory load. Prior to hearing each passage in the Hess and Foss experiment, the subject hears a set of five digits that he/she must remember. After listening to the passage and naming the target word, the subject must recall the digits. The motivation for including the digit recall task comes from studies (i.e. Baddeley & Hitch, 1974) that have found that when subjects have a concurrent memory load, performance on the primary task suffers. According to this line of thinking, we would again predict that those subjects with smaller working memory capacities would show an associative priming effect in the global unrelated - local related condition (different from the original Hess & Foss (1991) findings). Contrary to the predictions of study 1 however, we would predict that those subjects with larger working memory capacities would also show an associative priming effect in the global unrelated - local related condition. This outcome is predicted primarily because the concurrent digit load is assumed to take up a good portion of a subject's working memory capacity. If a subject's working memory capacity is being used up on the digit task, they will not be able to devote the resources to the task of comprehension that they normally would. As a result, it is predicted that those subjects with larger working carrying a concurrent memory load should perform similar to a person with a smaller working memory capacity without a memory load. Such a result provides support for the view that working memory capacity plays a substantial role in lexical processing.

One possible alternative outcome would have the smaller working memory capacity subjects showing an associative priming effect in the global unrelated - local related condition and the larger working memory capacity subjects

replicating the original Hess & Foss efficts (i.e. no associative effect). This outcome could potentially be explained by a difference in comprehension skill.

Study 3

The third study is a departure from the earlier two studies in that it is an attempt to find a "purer" measure of the articulatory loop. Remember the problem with using the letter span as the measure of the articulatory loop in studies 1 & 2 was that the letter span contains an executive component. When the central executive measure (alphabet recoding above) is obtained by partialing out the variance associated with an articulatory loop measure that has an executive component, we lose some of the executive measure. Finding an independent measure of articulatory loop capacity that does not have an executive component has the potential advantage of giving us a "purer" measure of central executive efficiency. In addition to meeting the short term goal of having a "purer" measure of the central executive, finding a "purer" measure of articulatory loop capacity allows us to address the longer term goal of defining the properties of the components of working memory more completely.

There were five different tasks used in this experiment all of which had minimal processing demands. The first two tasks attempt to measure the subject's rate of articulation. Use of this type of task seemed appropriate given the finding that rate of articulation is related to the number of items a person is able to recall. In the first articulation rate task, the subject is given a starting number (e.g. 301) and an ending number (e.g. 320). When the subject is ready to begin, he/she must count aloud as fast as possible from the start number to the end number as clearly as possible. The time it takes from beginning to end is the subject's articulation rate. In the second articulation rate task, the subject is given a starting number,

When the subject is ready to begin he/she begins counting aloud as quickly and accurately as possible. After a specified period of time the subject is told to stop counting and enter the number where he/she left off. The measure of interest is the amount of numbers per second.

The third and fourth measures are related to the nonword repetition task used by Gathercole & Baddeley (1989). In both the nonword tasks, subjects hear a nonword made up of CVC syllables that are infrequent in the English language. The nonwords range in size from two to eight syllables in length. One of the nonword tasks is a nonword repetition task. In the nonword repetition task, subjects hear a nonword and must simply repeat it back. The dependent measure of interest is the number of nonwords that the subject is able to repeat back correctly. The other nonword task involves making a same-different judgment of two nonwords. Again in this task, the dependent measure is the number of correct same-different judgments.

The fifth task to be used is the digit span task. The digit span task that will be used is exactly the same as the letter span task that is used in studies 1 & 2 (except that digits will be used of course).

The initial goal is to determine if performance on these tasks is highly correlated and to see if performance on the five tasks define a single articulatory loop factor when entered into a factor analysis. As was mentioned above, this is the first step in an attempt to further investigate the properties of the components of working memory.

Status report:
Due to the extensive programming involved in preparing the three studies, none of the studies are ready to be run at this point (6/29/91). Once the programmers at

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AFHRL have completed the programming we will run the studies. I will discuss the results from the studies in the follow-up grant proposal.

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Table 1

Global related - Local related

The banker had worked overtime and had earned enough to buy the car he had been admiring. He knew that if he bought the car he would barely be able to afford the insurance. Rather than risk being broke due to some unforeseen expenses, *the banker saved the* *money*

Global related - Local unrelated

The lifeguard had worked all summer and had earned enough to buy the car he had been admiring. He knew that if he bought the car he would barely be able to afford his college tuition. Rather than risk being broke due to some unforeseen expense, *the lifeguard saved the* *money*

Global unrelated - Local related

The banker and his family spent their vacation on the coast. The most exciting part of the vacation happened one day at the beach. While playing in the water with his children, the banker noticed someone struggling about 10 yards away. After rushing over *the banker saved the* *money*

Global unrelated - Local unrelated

The lifeguard thought it was going to be another uneventful day when, all of a sudden he saw something strange happening about 100 yards away from the beach. He took the lifeguard boat out to the disturbance. As soon as the boat arrived at the scene *the lifeguard saved the* *money*

Control

In this experiment you must name the last word of each passage. For this passage the last word is the *money*

VISUAL COGNITIVE PROFILE FOR PILOTS

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Abstract

U.S. Air Force pilots and control subjects performed seven visual cognitive tasks, each tapping into different underlying processing subsystems. We found that pilots visually rotate objects better than non-pilots, and that although pilots make categorical spatial judgments like non-pilots, they make strikingly better metric spatial judgments than non-pilots. Pilots' abilities to track motion, scan images and, extract visual features from objects--with or without visually noisy input--were like those of non-pilots. The results imply that specific processing subsystems are especially important for, and characteristic of, pilots. Different applications and uses of such research are discussed.

Visual Cognitive Profile for Pilots

People working within specific professions require distinct abilities to perform their jobs. These abilities may develop "on the job" through training and practice, or may be brought "into the job" because they are innate or develop in childhood. In either case, special abilities enable people to excel in specific occupations. Skills rely on a complex set of specific processing components that are pulled together to perform some task. Pilots--as members of a highly specific and professional occupation--rely heavily on a set of specific cognitive abilities and their corresponding underlying system components. Pilots require quick and accurate responses on a wide variety of tasks that depend on high-level visual cognition. High-level vision relies on the use of stored knowledge, in contrast to low-level vision--which is driven purely by the stimulus input. Research on low level vision has laid the foundations for many tests that examine abilities such as visual acuity, night vision, thresholds, field size, and so forth. In contrast, very little useful technology has been developed from research on high-level vision. Our research program is a step in the direction of remedying this deficiency.

Our research is an attempt to develop a high-level visual cognitive profile for pilots. High-level visual processing, like other cognitive abilities, breaks down into many specific computational components. Each processing subsystem corresponds to a black box that accepts a specific kind of input and produces a specific kind of output; the process of performing this mapping requires specific computations (for more details, see Kosslyn et al., 1990). The processing labor required to perform a cognitive function is divided among different component subsystems, which interact together to perform complex

and yet flexible information processing (Van Essen, 1985). The tasks used in this research examine specific processing subsystems that are involved in high-level visual processing required by pilots. The tasks tap into different subsystems and evaluate their performance in terms of response speed and accuracy. The tasks are based on extensive research done at Harvard University and at other research centers. Many of the tasks were successfully applied to account for neurological syndromes and used to test brain damaged patients (Kosslyn et al., 1990), healthy elderly subjects (Dror & Kosslyn, 1991), and children of various ages (Kosslyn, Margolis, Barrett, Goldknopf, & Daly, 1990). The tasks make use of neurophysiology, neuroanatomy, behavioral data, and computational analyses to decompose visual cognitive abilities into distinct processing subsystems.

The tasks administered in this research tapped into processes that involve motion tracking, extracting visual features and dealing with visually noisy input, spatial skills, scanning of images, and image rotation. The selection of these tasks was based on initial data collection on a wide variety of tasks and theoretical computational analysis of cognitive skills required by pilots.

General Method

Each task consists of a set of trials that require the subject to make a specific judgment. The difficulty of the trials is manipulated in order to force an underlying subsystem to engage in different levels of processing. The slope of increased response time and error as a function of difficulty of the trials reveals the increased amount of processing needed to perform the more difficult trials. Comparing the performance slope of pilots to that of control non-pilot enables one to determine whether pilots have a more efficient subsystem. By examining a number of such tasks, a visual cognitive profile of

pilots can be charted. This profile will specify which subsystems are particularly efficient in pilots, compared to non-pilots. In order to compose such a profile one must test pilots and control subjects on various tasks and compare the slopes of increased response time and error as a function of the difficulty of the trials. If there is no difference--the rate of increase in response time and error is identical between pilots and non-pilots--then there is no difference in the ability of the subsystem being examined. Any difference in overall response time and error rate (not slopes), in this case, must be caused by some other unrelated factor (e.g., speed of muscle movements that control the fingers that are pressing the response keys). However, if there is a difference--an interaction between the difficulty of the trials and the two groups of pilots/non-pilots, showing a significantly larger increase for the control subjects--then the pilots have a more efficient component subsystem.

The data for each task were analyzed by analysis of variance to determine wether such an interaction was observed. Response times greater than 2.5 times the mean of the remaining scores in each cell for each subject were treated as outliers and replaced by the mean of that cell. Incorrect responses were not included in calculating the response times.

In all tasks,. half of the trials should have been evaluated as "true" and the other half should have been evaluated as "false." The trials were always ordered randomly, except for the constraint that the same level of difficulty, or response, could not appear more than three times in succession. All tasks began with written instruction, followed by practice. During the practice trials the computer gave feedback by beeping if a wrong answer was given; during the actual trials no feedback was provided, and no talking was allowed. Each trial in the tasks began with an exclamation mark which signalled the subject that a new trial was about to begin. All tasks required the subjects to respond

by pressing keys marked "yes" and "no" on the computer's keyboard. Prior to administering the tasks, subjects were acquainted with the yes/no keys and practiced using them. The tasks were administered on a Macintosh computer. All subjects were stationed 18 inches from the computer screen.

Subjects

Sixteen pilots and 16 control subjects were tested on all seven tasks. The pilots and four control subjects were tested at the Armstrong Laboratory in the Human Resources Division at an Air Force base in Arizona. The additional control subjects were graduate and post-graduate students tested at Harvard University. The sex, age, handedness, and education of the control group was matched to those of the pilots.

Mental Rotation

Image rotation tasks show a linear increase in response time as the angular rotation increases (Cooper, 1975; Shepard & Cooper, 1982). Many researchers have explored this increase in response times as a function of the angular rotation by comparing the slopes of these functions for different groups (see Dror & Kosslyn, 1991, for an example).

The image rotation task used in this research required the subjects to tell whether two shapes were identical, regardless of their orientation. First, one shape was displayed on the screen. The subject was given as much time as he required to study it. After the subject pressed the space bar, the first shape was removed from the screen and the second shape was displayed. The subjects were required to decide whether the second shape was identical to the first, regardless of its orientation. The second shape was presented at one of four angular disparities relative to the first, 0, 90 135, or 180 degrees. This task is a modified version of the task devised by Shepard and Metzler (1971), which

revealed a linear increase in response time with the increased angular disparity.

Method

Materials. The shapes were composed of two or three connected bars, each made out of 0.6 x 0.6 cm squares. The shapes never exceeded 2.6 x 3.2 cm. The first shape was always presented upright and its top was painted black. The same segment was painted black in the second shape, indicating to the subjects the angular disparity it had from the first 'upright' shape.

Procedure. The first upright shape was presented. The subjects pressed the space bar after they had memorized this shape and were ready to view the second shape. When the second shape was presented, the subjects pressed the appropriate response key to indicate their judgment of whether the two shapes were identical or mirror reversed images.

Results

As illustrated in Figure 1, an analysis of variance showed an interaction in the response times between subject group (pilots vs. non- pilots) and angular disparity, $F(3,90) = 8.13$, $p = .0001$, which reflected a smaller increase in time with angular disparity for pilots. An overall increase in response time with the increase angular rotation was significant as well, $F(3,90) = 30.18$, $p = .0001$, as well as an overall difference between pilots and non-pilots, $F(1,30) = 6.75$, $p = 0.0144$. In addition, an overall increase in error rate was observed with greater angular disparity $F(3,90) = 15.0577$, $p = .0001$. No other significant differences were found with error rates, $F < 1$ for the interaction and for the overall difference between pilots and non-pilots.
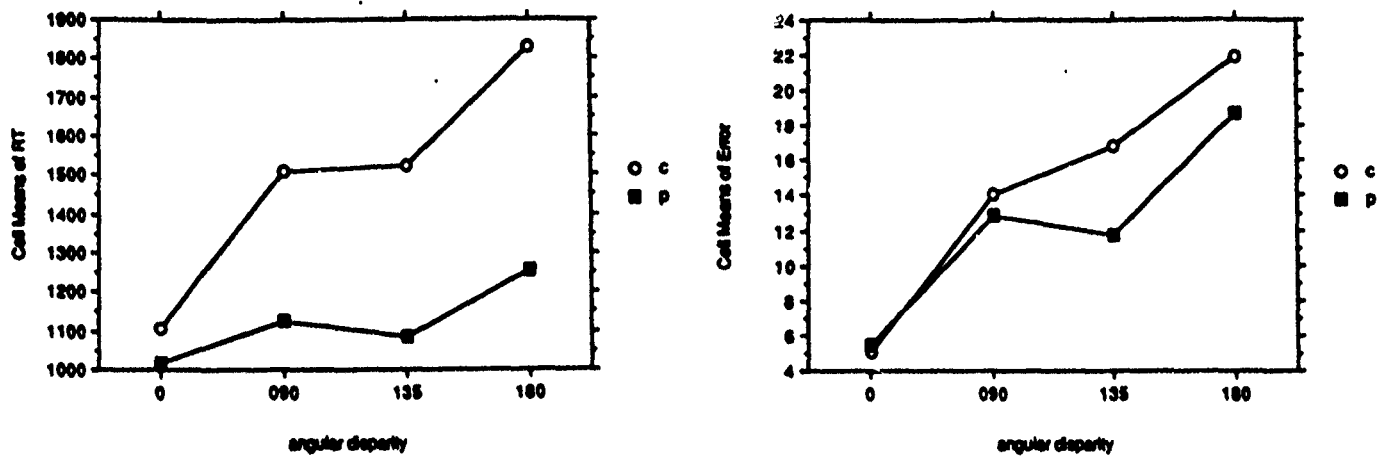
Figure 1: The results from the image rotation task.

As illustrated in Figure 2, the pilots themselves formed two distinct groups. Whereas one group of pilots (9 out of 16) showed some increase in response time with greater angular disparity, the other group (the remaining 7) showed no increase--sometimes even a decrease--in response time with larger angular disparities. An analysis of variance showed that the slopes of the two pilot groups were significantly different $F(3,42) = 11.0$, $p = .0001$.

Angular Disparity	0	90	135	180
Group A	930	1101	1102	1377
Group B	1131	1156	1063	1100

Table 1: Mean response times for the two groups of pilots.

Discussion

The results of the mental rotation task are extremely interesting. Not only do the results show that pilots rotate visual objects better than non-pilots, they also suggest that whereas some pilots are simply faster than non-pilots, other pilots are qualitatively different in the way they perform the task. Some pilots reported in a post-debriefing session that they automatically saw the two images as identical and in order to say whether they were originally identical or mirror-reversed they had to reconstruct in their mind in what way they had transformed the object. A careful examination of the pilots who do not show the increase in response time did not show any apparent common characteristic: they do not fly different types of planes, they do not have different flight experience, they vary in the amount of time since they have last flown, and they vary in age. Additional exploration and analysis are required to examine this fascinating phenomena.

Motion Tracking

The motion task required the subjects to perceptually track a moving object and then to continue to track it using visual mental imagery. The subject viewed a moving ball on the computer screen. The ball moved in a constant circular trajectory at constant speed. After roughly two full circles the ball disappeared from the screen and the subjects were required to imagine that the ball was still moving on the screen. After a delay an X mark was flashed on the screen. The subject had to decide whether the X appeared at the exact position where the ball should have been, if it had not disappeared. The X mark appeared either at the point where the ball should have been, or before or after that point.

Method

Materials. The task required the subjects to track a black ball on the computer screen. The ball had a diameter of 1 cm and moved in a circular trajectory around the center of the screen. The circular trajectory was divided into 30 positions with equal angular disparities of 12 degrees. Motion was created by flashing the ball at each of the thirty positions for 183 ms. Accordingly, it took 5.49 seconds to complete one full circle. The diameter of the trajectory was 10.8 cm (measured from the center of the circle to the center of the moving ball).

The ball moved on the screen for about two full circles (on half of the trials it disappeared after completing 12 degrees more than two full circles, and on the other half of the trials it disappeared when it was 12 degrees before completing the two full circles). After the ball disappeared the subjects continued to track it using visual mental imagery, as if the ball continued to move in the same trajectory and speed. After a time delay, varying from 549 ms to 1281 ms, an X mark appeared on the screen for 183 ms and then the screen went blank. The X mark either was where the ball was supposed to be, or 12 or 24 degrees before or after that position. Easy "on" trials had relatively brief time delays, whereas easy "off" trials included a great disparity between the location of the X mark and the actual position of the ball.

Procedure. The ball moved along its trajectory and the subjects were required to track its motion. After the ball disappeared the subject kept tracking it in their imagination. When the X mark appeared they responded by indicating whether they judged the X mark to be where the ball should have been.

Results

The analysis of data was divided into two parts. In the first part, we considered the trials where the X mark was not presented where the ball should have been. In this case the difficulty of the trials was manipulated by the distance between the X mark and the position where the ball should have been. As illustrated in Figure 3, the more difficult trials demanded significantly more time, $F=(1,28) = 7.60$, $p = .0101$, and more errors were made, $F=(1,28)$ 38.71, $p = .0001$. No interaction was found between pilots/non-pilots and difficulty $F < 1$ for response time and for error rates. Nor was there a significant difference between the pilots and the non-pilots, $F < 1$ for both dependent measures.

In the second analysis, we considered the trials where the X mark was presented where the ball was supposed to be. As illustrated in Figure 3, the longer delay times did not significantly increase the response times, $F < 1$, but did increase the error rates, $F(2,54) = 5.16$, $p = .0089$. No interaction between pilots/non-pilots and the delay times was found, $F < 1$ for response times and error rates. The difference between pilots and non-pilots was not significant in response time, $F < 1$, and only a marginally significant trend was observed in error rates, $F(1,27) = 3.0008$, $P = .0946$.

Distances between probes and position

Delay times for the probe
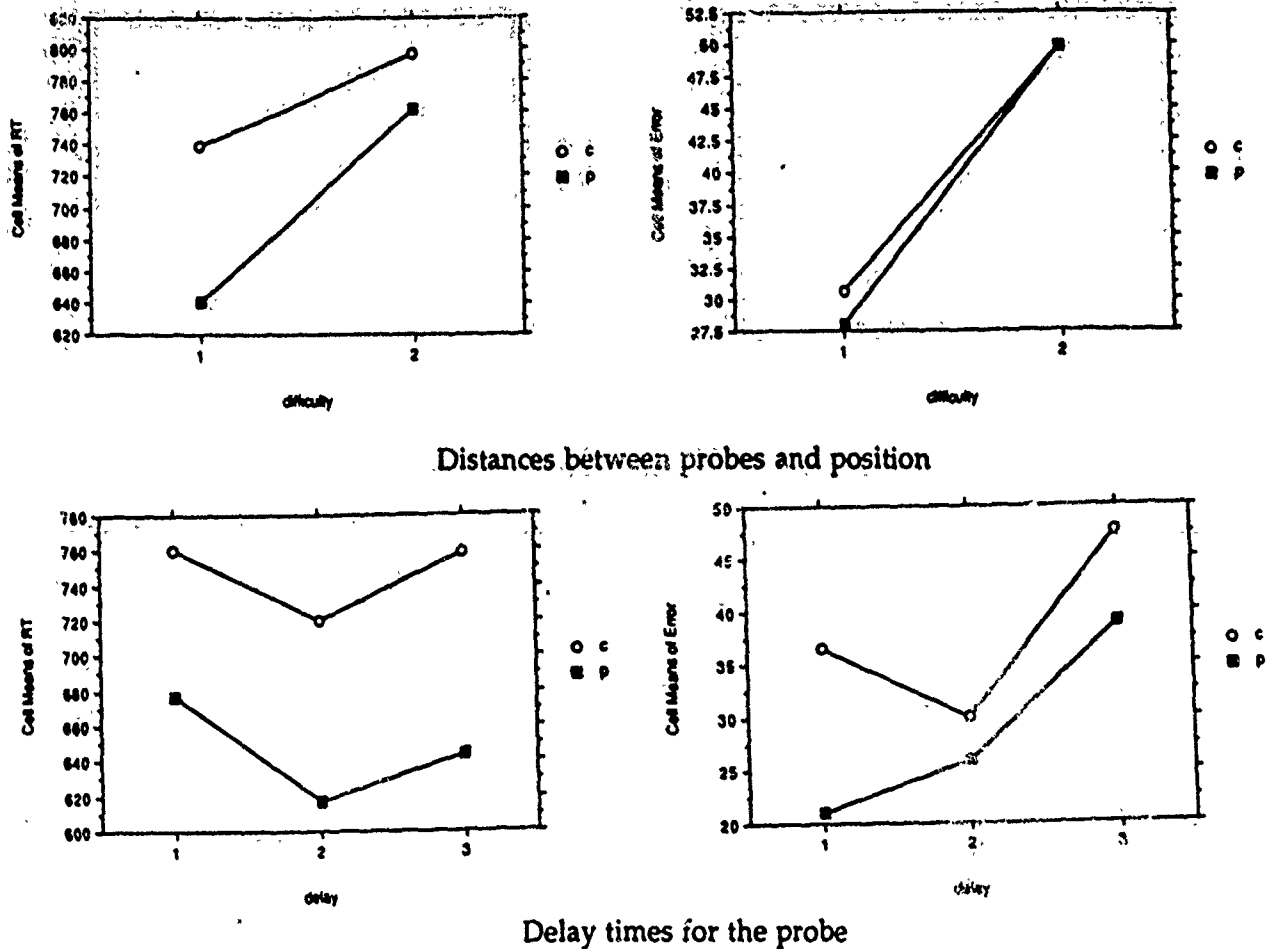
Figure 3: The results from the motion task.

Discussion

The motion task did not reveal any difference between pilots and non-pilots, although the increasing time delays and distances of the X probe did affect the performance of the subjects. This motion task was extremely difficult, as witnessed by the high error rates. Thus, it may have been insensitive to any actual differences between the groups. The task should be modified and made easier so more careful observation might be made.

Spatial Relations Encoding

Two spatial tasks were administered, one examined categorical spatial judgments whereas the other examined metric spatial judgments. The tasks used here are the same tasks used by Kosslyn et al. (in press) where experimental data, computational analyses, and computer simulations have suggested that categorical and metric spatial relations are computed by separate processing subsystems. A categorical spatial relation corresponds to a category, such as above, below, left, right, connected to, and so forth; these categories group over metric variations. The categorical task we used here required the subjects to decide whether an X mark was above or below a bar. The distance of the X mark from the bar was varied to manipulate difficulty. In the metric task the subjects were required to decide whether an X mark was within half an inch of the bar. The distance of the X mark from this criterion point was varied to manipulate difficulty. The tasks used here were also used by Kosslyn et al. (1989), and a variant of these tasks were used by Hellige & Michimata (1989).

Method

Materials. The bar had a constant width of 0.6 cm and a length of 2.4 cm. The X mark was 0.4 x 0.4 cm. The trials were classified into different levels of difficulty depending on the location of the X mark. For the categorical spatial judgment, the trials that had the X mark near the bar were classified as difficult, whereas the trials where the X mark was far from the bar were classified as easy. For the metric spatial judgment, the trials were considered difficult if the X mark fell near the half inch boarder from the bar.

Procedure. In each trial the bar and X mark were presented on the screen. The subjects had to make their judgments (whether the X was above the bar for the category task, and whether the X was within half an inch from the bar for the metric task) and respond accordingly by pressing the yes/no keys. Prior to the metric task, the subjects were shown an example of the half-inch distance on the computer screen.

Results

As illustrated in Figure 4, the analysis of variance in the categorical spatial judgment showed that there was no significant interaction between pilots/non-pilots and difficulty of the trials, $F(1,30) = 1.0651$, $p = .31$ for response time, and $F < 1$ for error rates. Pilots had faster overall response times than non pilots $F(1,30) = 7.31$, $p = .0122$, but no difference was found in error rates, $F(1,30) = 2.1937$, $p = .1490$.

In contrast, the analysis of variance for the metric spatial judgment data revealed a significant interaction between the pilots/non-pilots and the difficulty of the trials, $F(1,30) = 6.80$, $p = .0141$ for response time, and $F(1,30) = 3.63$, $p=.0664$ for error rates. In addition, the pilots had overall faster response times than non- pilots, $F(1,30) = 12.48$, $p = 0.0014$, but were no more accurate, $F < 1$ for error rates.

A difference score was obtained for each task in each group by finding the mean difference between the easy trials and the difficult trials. As illustrated in Figure 4, the analysis of variance on the difference score showed not only a significant difference between the performance of the two groups on the two tasks, $F(1,30) = 31.58$, $p = .0001$ for response time, and $F(1,30)$ 24.0, $p = .0001$ for error rate, but also a significant interactions between the pilots/non-pilots and the two tasks $F(1,30) = 7.72$, $p = .0093$ for response time, and $F(1,30) = 6.77$, $p = .0142$ for error rates.
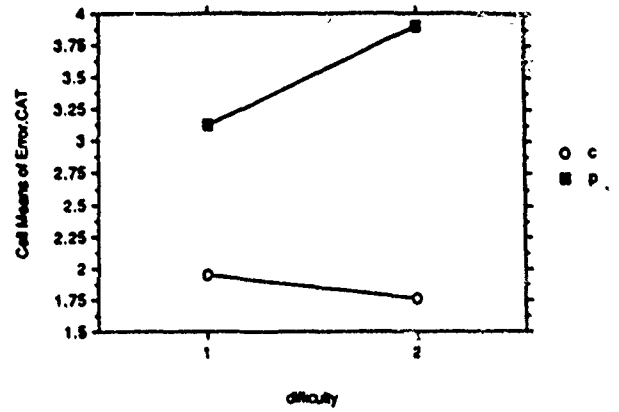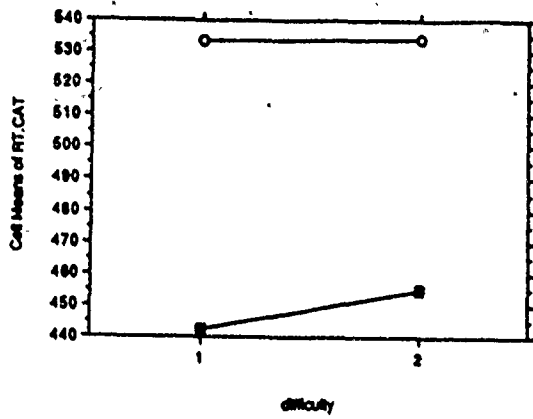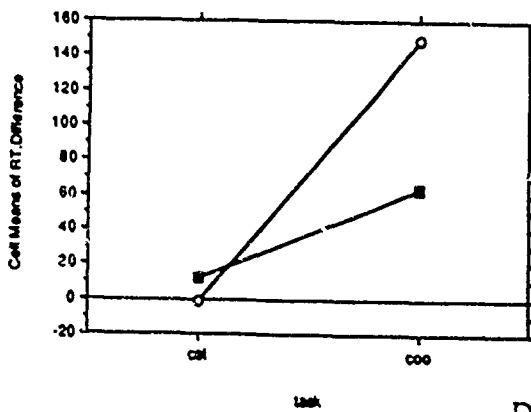
Catecorical judgement task
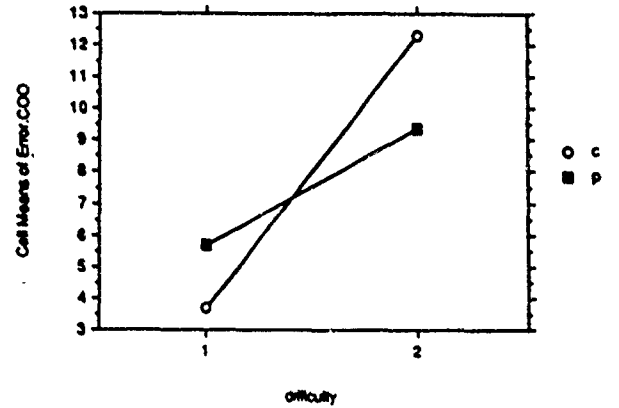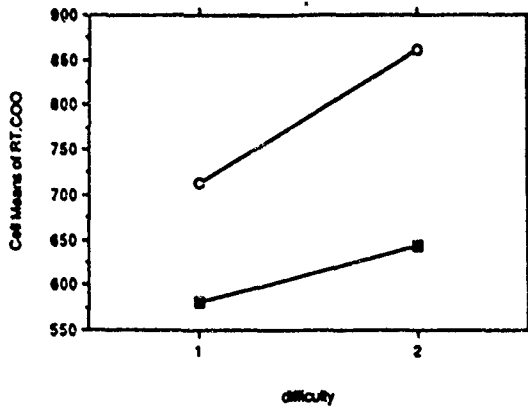
Metric judgement task
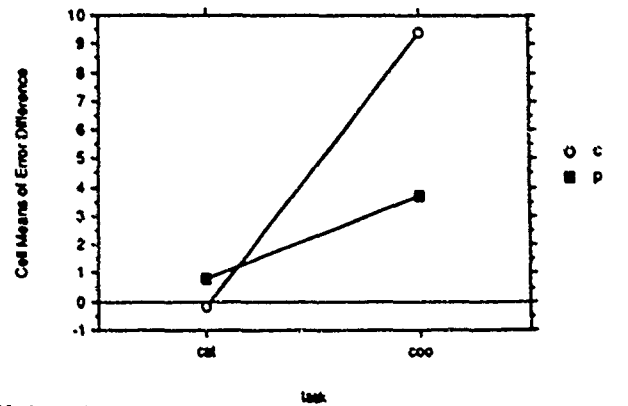
Difference score

Figure 4: The results from the spatial judgement tasks.

Discussion.

When categorical spatial judgments were made, the pilots responses and errors were like those of non-pilots. However, when metric spatial judgments were made, the pilots performed much better--in response time and in error rates--than non-pilots. The results here further strengthen the claim that categorical and metric spatial judgments are computationally distinct.

Recovering Visual Features

Two separate tasks were used to examine the ability to recover visual features from an image and to deal with visually noisy input. In the first task the subjects saw a curvy shape and an X mark, and were asked to decide whether the X mark was on the shape. Three different sizes of shapes were used. The second task was identical to the first, except that "noise" lines were imposed over the stimulus, which made the task of finding the shape and the X mark more difficult.

Method

Materials. The shapes were constructed by connecting 1, 2 or 3 curvy edged bars. The bars had a width of 0.6 cm and their length varied from 0.6 to 2 cm. The X mark was 0.6 x 0.6 cm. The X mark fell on the figure for half the stimuli at each level of complexity, and fell off the stimuli for the other half. For the distractor task, the same stimuli were presented, but now were covered by eight curvy lines, which were placed randomly in the center of the screen.

Procedure. A curvy shape and an X mark were presented on the screen. The subject was asked to decide whether the X mark was on the shape.

Results

As illustrated in Figure 5, no significant differences between pilots and non-pilots were found in either of the tasks here. In the on/off task without the added noise, the interaction between pilots/non-pilots and the complexity of the image was F < 1 for response time and error rate. There was however a significant difference between the trials of different complexity, $F(2,60) = 3.16$, $p = .05$ for response time, and $F(2,60) = 3.84$, $p=.0270$ for error rate. No significant overall difference was found between pilots and non-pilots $F(1,30) = 2.83$, $p = .10$ for response time, and $F(1,30) = 1.42$, $p= .24$ for error rate.

Similar results were obtained from the corresponding task with the added visual noise. The interaction analysis resulted with an $F(2,60) = 1.13$, $p = .33$ for response time and F < 1 for error rate. In this task there was an overall difference in response time between pilots and non- pilots $F(1,30) = 9.10$, $p = .005$, and a trend for a difference among the different levels of complexity, $F(2,60) = 2.57$, $p = .08$. The corresponding error rates were not significant, F < 1 for the overall difference between pilots and non-pilots, and $F(2,60) = 1.38$, $p = .26$ for the effects of complexity.

To examine further how the added noise might have affected the performance of the two groups, a difference score between the two tasks was obtained. For each level of complexity in the trials, the mean data from the experiment without the added noise was subtracted from the mean data from the corresponding level of difficulty from the experiment with the added noise. As illustrated in Figure 5 the difference score analysis of variance did not reveal any effect of the added noise, except for increased error rate for the more complex trials $F(2,60)= 3.43$, $p = .0390$.
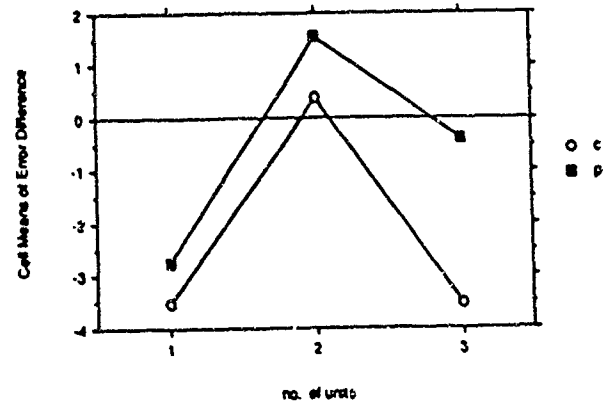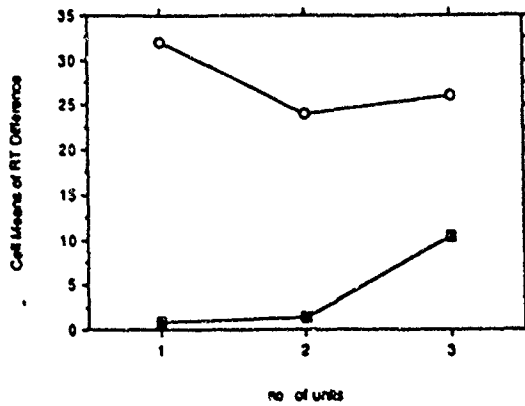
Discussion

Extracting visual features from images, with and without visual noise, is processed the same way by pilots and by non-pilots.
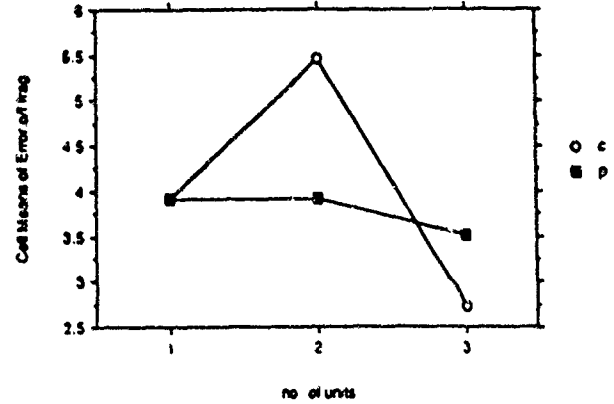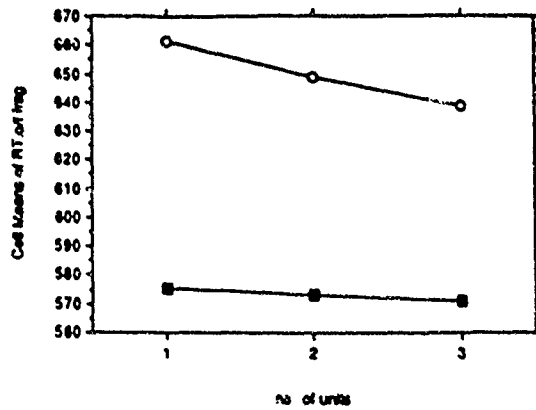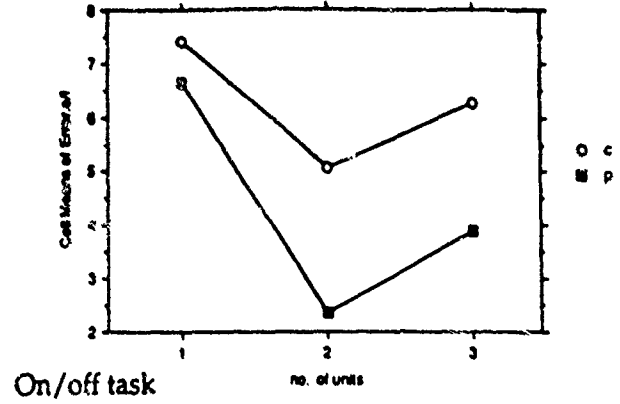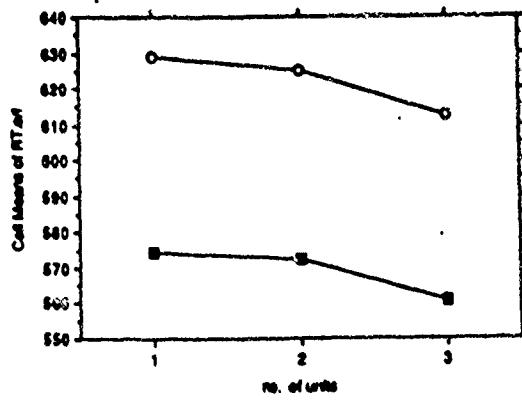
On/off task

On/off task with visual noisy input

Difference score

Figue 5: The result from the recovering visual features task.

Scanning Images

The image scanning task required the subjects to scan a rectangular-ring shape. The ring was composed of a perimeter of white and black squares and the subjects were asked to judge whether an arrow was pointing to a black square (for more details, see Dror & Kosslyn, 1991). The subjects were first allowed to study the shape, then an arrow was flashed within the rectangular-ring. The arrow appeared in different places within the rectangular shape, and was presented in any number of orientations. Following the brief flash of the arrow, the shape and the arrow were withdrawn. The subjects were to decide whether the arrow pointed to a black or white square. All the rectangular-ring shapes had three black squares, which were located in different places along the perimeter. The trials embodied three levels of difficulty, reflecting the distance of the arrow from the perimeter of the rectangular ring. This experiment is a variant of the experiment reported by Finke & Pinker (1982), who found increasing response times when increasing distances had to be scanned.

Method

Materials. The ring was constructed from twenty 0.7 x 0.7 cm squares, with six squares on each side, giving it an overall size of 4.2 x 4.2 cm. On each trial three different squares were painted black, each on a different side of the ring. The 0.4 cm arrow was flashed pointing either north, north-east, east, south-east, south, south-west, west, or north-west. The arrow was either 2.1 cm, 1.2 cm, or adjacent to the target square.

Procedure. The subjects were presented with the rectangular-ring, and pressed the space bar when they had memorized the locations of the three black squares. Following this, an arrow was presented for 50 ms, after which

all stimuli were removed from the screen. The subjects then indicated whether they thought the arrow pointed to one of the blackened squares.

Results

As illustrated in Figure 6, the analysis of variance did not show significant interactions between the pilots/non-pilots and the scanning distances. However, for both groups significantly more time was needed to scan greater distances, $F(2,60) = 73.57$, $p = .0001$, and more errors occurred with greater distances, $F(2,60) = 34.90$, $p = .0001$. The general response time for pilots was faster than that of non-pilots, $F(1,30) = 6.32$, $p = .0175$, but pilots were no more accurate than non-pilots, $F < 1$.
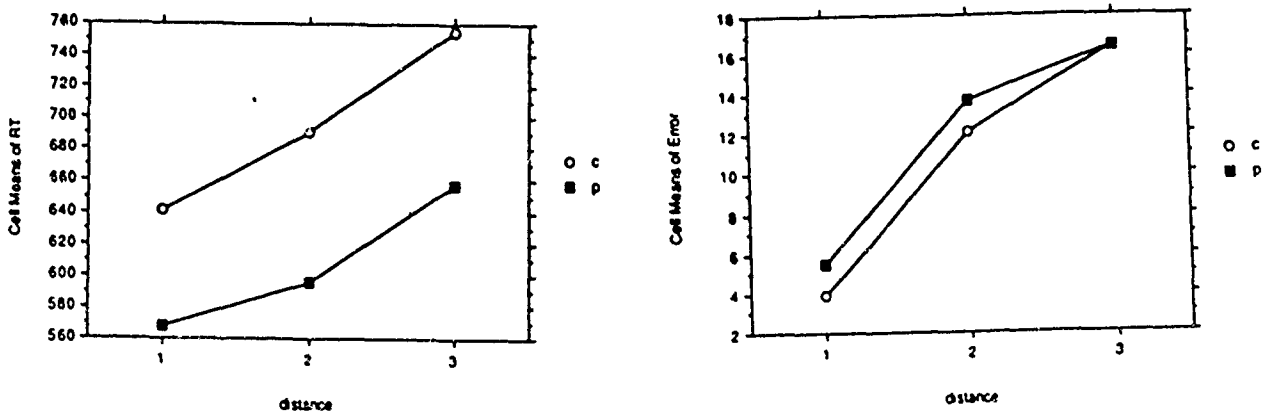
Figure 6: Results from the image scanning task.

Discussion

Pilots and non-pilots scan mental images the same way. Both groups show a similar increase in response times and error rates as the scanning distance increases.

General discussion

Seven tasks were administered to pilots and control non-pilots in order to characterize the pilot's distinctive cognitive abilities. In each experiment we considered the effects of varying difficulty in a specific way, which should have selectively taxed one subsystem. Each of the tasks included trials with varying levels of difficulty. As illustrated in Table 2, we found that on some of the tasks the changes in performance with increased levels of difficulty were identical in pilots and non-pilots. But on other tasks the pilots were not affected as much when we taxed the subsystem as were the control non-pilots. On these tasks we found the pilots performance remarkable. The pilots could engage in increasing levels of processing without sacrificing response time or error rate as much as the non-pilots.

This finding was most impressive for mental rotation task. Although some pilots were simply faster at rotating images than were the controls, other pilots were not affected at all by the increasing levels of difficulty. In the spatial relations encoding tasks the pilots' abilities varied with different types of spatial processing. Although the pilots performed like the control subjects on categorical spatial processing trials, they were significantly better on the metric spatial trials.

Task	Pilots' ability
Image rotation	superior
Motion	normal
Spatial - Categorical	normal
Spatial - Metric	superior
Extracting Features from Image	normal
Extracting Features from Image - with noisy input	normal
Scanning images	normal

Table 2: Summary of pilots' performance.

Pilots possess remarkable high-level cognitive abilities. Such abilities are in essence a complex computational process, which is achieved by computational division of labor between different components subsystems that interact with each other. The impressive abilities the pilots have are achieved either through superior processing subsystems that process computations more efficiently or though superior strategies that incorporate different interactions between the component subsystems, or both.

The pilots' remarkable spatial metric ability is probably due to a superior components subsystem, probably located in the right parietal lobe (see Kosslyn & Koenig, in press), that enables quick and accurate metric spatial computation to be carried out.

The impressive image rotation abilities of pilots is a more complex issue. The image rotating task requires one to mentally transform and move an imaged pattern. This encompasses a set of complex computations that

probably involve parietal and frontal lobe structures (Deutsch, Bournon, Papanicolaou, & Eisenberg, 1988). The subset of pilots who rotate fast may simply have a superior underlying subsystem. Such an enhanced subsystem has the ability to engage in more computational processing needed for the extra angular rotation without being forced to require much more time to do so. The second group of pilots, who do not need any additional time to rotate objects at greater angular disparity, may use a different strategy than the other subjects. Thus, either the subsystems involved here are different than those in the first group and the general population, or the same subsystems are used but they interact together in a unique and unconventional way. Further research is necessary in order to understand the processes going on in each group and to categorize them better.

The research reported here suggests that in some cases pilots might be using different strategies to manipulate visual images and make visual judgments. In other cases, pilots might differ in the way they divide complex cognitive computations into subprocesses. And still in other cases, some of the pilots subsystems are just extraordinarily efficient. This research is the first step in formulating a visual cognitive profile for pilots. Such a profile will indicate which components and strategies for computational processing are distinctive for pilots and characterize the computations needed for flying skills.

Applications

A better understanding of the cognitive skills needed by pilots has many important applications.

1. *Screening flight cadets.* The tests used today to screen flight cadets focus on low-level visual processing. The tests that do attempt to tap onto higher visual processing are "shots in the dark," which are not based on an

understanding of the underlying components and computations that comprise the skills needed by pilots. A cognitive profile for pilots can facilitate the process of screening flight cadets. This research does not presume to determine whether the visual cognitive abilities that characterize pilots are abilities that are "brought in" by potential pilots, or whether the training and practice the pilots receive causes these abilities to develop. To answer such a question a longitudinal study is required. Flight cadets entering the undergraduate flying course should be tested on their cognitive abilities, and re- tested again after they graduate. In any case, this and further research can help detect promising pilots. It can also be used to evaluate pilots cognitive abilities by testing processing subsystems that are especially important for pilots.

2. *Teaching procedures.*   A cognitive profile for pilots can help build and evaluate courses and teaching procedures. A better understanding of what a good pilot is "made of" can help to direct activities that enhance the specific skills needed by pilots. One can evaluate teaching procedures and simulators by testing participants before and after their training.

3. *Direct pilots' careers and training.*   The cognitive profile can help to classify pilots into various tracks in the air force. For instance, it can determine which pilots have cognitive skills that are more apt for flying certain types of airplanes. The tasks that tap onto different processing subsystems can also be used to predict which pilots might benefit more from certain training programs, and thus help direct pilots to different training courses and simulators.

Footnotes

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VISUAL ATTENTION and OPTIMAL SEARCH

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ABSTRACT

Optimal search theory was used to determine whether observers allocate attention to a visual display optimally, given prior probabilities of target location. A location cuing paradigm with various probabilities of cue validity was used to measure observers' accuracy as a function of stimulus onset asynchrony (SOA). The general findings were that observers may be either optimally allocating a fixed amount of attention, or increasing the amount of total attentional resources, in response to task demands.

INTRODUCTION

Models of visual attention use metaphors that lead to the image of attention as an entity of some sort which is employed to increase processing of certain items in a field or to focus on certain attributes of a stimulus. The metaphors are useful in that they describe the time-course and nature of selective processing, but it must be emphasized that attention is not a thing but rather a process of a system. This paper will summarize the findings of a 10-week research project funded by the AFOSR Summer Research Program in 1991, on visual attention.

Many of the recent studies of visual attention present stimuli on a computer screen and measure observers' processing speed to targets at different locations in the visual field, in order to explore metaphors of attention based on physical entities. Tsal (1983) found that attention was like a spotlight moving across the visual field at a constant speed (1 deg per 8 msec), and that processing ceased during the movement. Cheal and Lyon (1989) later showed evidence against the spotlight model. Erickson and St. James (1986) modeled attention as a variable-size zoom lens with more concentrated attention at the center and a tapering off at the edges. LaBerge and Brown (1989) and also Shulman, Wilson and Sheehy (1985) found support for a gradient model, with different "concentrations" of processing resources (attention) allocated to different areas of the visual field.

Other researchers have found that attention can be allocated voluntarily to disparate regions of the visual field. Egly and Homa (1984) found that subjects could attend to a ring-shaped region, and Podgorny and Shepard (1983) found that subjects could attend to different blocked shapes in a 3x3 grid.

The different findings for allocation of attention highlight the fact that attention can be employed flexibly in order to meet task demands, and that any single metaphor for attention has problems being descriptive at all levels and is thus probably too constraining. Other researchers have concentrated on attention as an allocation of resources

while remaining agnostic about the specific mechanisms involved. Sperling (1983) looked at performance tradeoffs in attentional tasks due to observers' focusing of attention to certain areas in a visual field. He plotted performance in a manner theoretically similar to signal detection theory, and found AOC (attention operating characteristic) curves that were analogous to the ROC (receiver operating characteristic) curve of signal detection. The AOC curve is shaped like the ROC curve, but instead of representing a given sensitivity, the AOC represents the range of performance at a given level of processing capacity. Sperling and Melchner (1978) found that instructions to devote different proportions of attention to various areas in a visual field yield performance lying on one AOC curve, but in different locations on that curve. They interpreted these results to mean that observers could allocate a fixed gross amount of processing capacity to different areas, with a defined pattern of tradeoffs: more capacity allocated to certain areas meant less capacity for other areas.

Sperling's observers were able to allocate attention voluntarily, according to instructions. In contrast, Shaw and Shaw (1977) studied the allocation of attention as a function of stimulus qualities. They varied the a priori probabilities of targets appearing in certain areas of a display in order to investigate the optimality of attention allocation. Following the work of Koopman (1956 & 1957) who defined optimal search for a given probability distribution

of target locations and a given amount of resources, Shaw and Shaw hypothesized that the total amount of attentional resources, phi, would remain constant across conditions of different probability distribution. They also predicted that observers would employ attentional resources in an optimal fashion for any particular distribution, so as to maximize the probability of correct detection. They manipulated probability distributions for targets appearing in different locations on a display, and found that observers had a fixed amount of resources (phi) that was employed optimally.

The goal of this experiment was to investigate the allocation of resources in a location cuing task such as that used in the work of Cheal and Lyon (1989, in press), and also Cheal, Lyon and Hubbard (1991). The location cuing paradigm uses a cue to direct attention to one of four locations equidistant from a fixation point, followed by a target stimulus and a mask, whereupon the subject attempts to identify the target at the cued location. Accuracy is measured at different cue-target stimulus-onset asynchronies (SOA) and it has been found that accuracy increases as a function of SOA until it begins to level off (asymptote) at 100 to 150 msec (Cheal and Lyon, 1989). The SOA by accuracy curve enables one to follow the timecourse of the build-up of attention at the cued location. The experiments showed that attention takes about 100 msec to "concentrate on" a cued location, in order to extract the maximal amount of information about the target (Lyon, 1990).

The rationale behind the current experiment is that attention can be deployed in order to maximize accuracy, given a particular probability distribution for target location. In the location cuing paradigm, attention can be seen as containing a gradient of resources concentrated at the cued location. This experiment was designed to apply the Shaw and Shaw (1977) optimality analysis to the Cheal and Lyon location cuing paradigm, in order to investigate whether observers can allocate resources in different distributions for different probability distributions, in an optimal fashion.

Accordingly, three different within-subject conditions were presented. In the 100% condition, the cue would always indicate the correct target location and the observer's optimal strategy would be to concentrate all possible resources at the cued location. In the 75% condition, a trial in which the cue correctly indicated the position of the target (on 75% of the trials) was termed a valid trial; conversely, trials in which the target appeared in an uncued location (on 25% of the trials) was called an invalid trial. Optimal performance would maximize overall accuracy across valid and invalid trials by allocating most of the attention to the cued location, but allocating a proportion of the total attention to the uncued locations. The 50% condition (50% valid and 50% invalid trials) would prescribe an optimal allocation where less resources would be allocated to the cued locations but more to the uncued locations, as

compared to the 75% condition.

According to optimal search theory (Koopman, 1957), resources would be allocated optimally not by matching to probability, but by matching to the natural log of probability, assuming a negative exponential return function for the employment of resources. The first prediction for this experiment was that attention would be allocated in this optimal fashion.

The second prediction in this experiment was that the sum total of resources, phi, would be found constant over different probability distributions, as in Shaw and Shaw, 1977. The third prediction was that phi would grow in time and reach a maximum at about 100 msec.

METHOD

Observers

Three observers were paid $7.00 per hour for a total of about thirty one-hour sessions. All were males between the ages of 19 and 33 with normal vision. One observer failed to complete the required number of sessions by the deadline date; therefore, his data are not included in the analysis.

Apparatus

Stimuli were displayed on an IBM-XT with a color monitor. An adjustable head and chin rest fixed the eye-to-screen distance at approximately 37 cm. Eye movement was monitored with a video camera to ensure that the observers fixated their gaze at a single location, and that observers maintained the proper head position. Responses were

recorded on the numeric keypad of a standard IBM keyboard.

Stimuli

Stimuli were presented as white pixels on a dark gray background, with a total luminance of 80 cd/m^2. Targets consisted of T's which could appear in one of four locations six deg. from a central fixation point, and in one of four orientations (pointing right or left sideways, up or down).

Procedure

Observers were seated in front of the screen, with their head position fixed by the chin support. Screen refreshes were made every 16.7 msec, so that the duration of any stimulus, target etc. was a multiple of 16.7.

The order of events in each condition was identical (see Fig. 1). A fixation bar appeared for 668 msec, followed by a 16.7 msec cue appearing at one of four locations. The cue was followed by a target at one location, and circles at the other three locations, after a variable stimulus-onset asynchrony (SOA). SOA's used were (rounded to the nearest msec) 0,33,67,100,133,167,200, and 233 msec. Following the presentation of the target, a mask was presented which was a composite negative image of all possible targets at all possible locations. The observer's task was to indicate, by pressing the corresponding arrow on the numeric keypad, which direction the target was pointing. The subject was instructed that accuracy, and not speed, was required.

There were three conditions which consisted of different probabilities of cue validity (the cue indicating correct location of the target). In the 100% condition, the cue always indicated the correct position of the target. In the 75% condition, the cue indicated the correct target location on 75% of the trials, but on 25% of the trials the target would appear at any one of the uncued locations with equal (8.3%) probability. The 50% condition was similar to the 75% condition except for 50% correct (valid) cuing and 50% incorrect (invalid) cues, split 16.7% among the uncued locations. Conditions were not intermixed within sessions; observers were also clearly informed as to what condition was running in each session.

Each observer was first instructed in the task and run for a number of sessions at the 100% level for training purposes. Target durations were individually determined for each subject on the basis of performance in the training sessions. Each observer was presented with a mixture of two target durations, 33 and 50 msec. Each observer was exposed to 18 sessions of 1028 trials: six sessions each at the three probabilities, with an equal number of trials at each SOA, and counterbalanced across cue and stimulus location, direction of target, and target duration.

Data was collected in the form of accuracy scores (by SOA) for valid and invalid conditions, by individual observer. Three analyses for each observer were planned: an analysis of shape of SOA curve by condition, an analysis of AOC, and a calculation of phi (total attentional resources)

for each condition as per Shaw and Shaw (1977).

RESULTS and DISCUSSION

Accuracy vs. SOA curves have been used to analyze data from similar paradigms in the past (Cheal et al, 1991; Cheal and Lyon, 1989). Improvement in accuracy by SOA indicates that, at longer SOA's, subjects are able to employ more attentional resources to the task with a corresponding increase in accuracy. The asymptotic level of accuracy indicates that the full amount of attention has had time to accumulate, and specifies the data limitation to the task (maximum performance possible). Figure 2 illustrates SOA curves for the individual observers.

Each line represents accuracy by SOA by condition: 100%, 75% (valid trials), 75% (invalid), 50% (valid) and 50% (invalid). Both sets of SOA curves show the predicted growth in accuracy up to 100 msec, with a subsequent leveling off. It was predicted that the curve for 100% would lie above the other two valid curves; in both observers the 100% curve is overlapping them. The overlap indicates that, in the 75% and 50% conditions, performance on cued locations is not impaired (relative to the 100% condition) by having, on some trials, to attend to targets at uncued locations.

For obs #1, the 75% valid curve lies above the 50% valid curve at all SOA's, and the 75% invalid curve lies below the 50% invalid curve. This was the predicted pattern and indicates that Obs #1 is allocating more attention to

the cued area and less to the uncued area, in the 75%
condition as compared to the 50% condition. Observer #2 did
not show the predicted SOA pattern, and thus could be judged
as not allocating his attention using probability
information.

Figure 3 shows the results of the AOC analysis. The
AOC curve for observer #1 shows a migration "outward" along
concentric AOC curves for SOA's between 0 and 67 msec,
indicating a growth in an underlying attentional resource,
similar to the approach to asymptote of an SOA curve.
Points for SOA's between 100 and 233 msec all lie
approximately along the same curved AOC line. As would be
predicted, points in the 75% condition lie mostly to the
left of points in the 50% condition, indicating that 75%
points increase accuracy in the cued location at the
"expense" of accuracy in the uncued locations, while 50%
points make the converse tradeoff. The data for observer
#2, consistent with the lack of allocation seen in the SOA
curves, show no difference between 75% and 50% points.

For the analysis of total attentional resources (phi),
Koopman's (1957) model for optimum allocation of searching
effort, as modified by Shaw and Shaw, 1977, was used.
Briefly, the steps are as follows: (1) plot probability of
target location by cued vs uncued position (the function
$p(x)$), (2) estimate the Lagrange multiplier lambda as the
line drawn above which the area of the probability curve is
the overall accuracy, (3) estimate phi as the area of the

curve between ln p(x) and ln lambda. For a detailed
exposition of the technique, the reader is referred to the
above two sources.

Figure 4 shows phi by SOA curves for the two observers.
Observer #1 shows almost identical values for phi at each
SOA for the 75% and 50% conditions. Phi is shown to rise
linearly from 0 SOA to a maximum at 67 msec SOA, whereupon
phi levels off and decreases. Note that phi for the two
conditions has the same value even though SOA curves show
different patterns of performance across 75% and 50%
conditions. The interpretation is that a fixed amount of
processing resources is applied, but with a different
allocation. In contrast, phi for the 100% condition is
lower than in the 75% and 50% conditions, at all SOA's,
indicating that a lesser amount of attentional resource is
required to perform in the valid-only condition. The phi
curves for observer #2 indicate that, as task "difficulty"
(uncertainty of target location) increases, total resources
employed goes up, for every SOA.

A problem of determining whether observer #1 allocated
his attention optimally has arisen from the fact that a
detailed analysis of accuracy by cued/uncued areas must
account for only the increment of accuracy above baseline.
Guessing accuracy is 25%, but it appears that baseline is
somewhere above that, due to an imperfect mask or some other
factor that allows post-exposure processing. A follow-up
experiment will be designed to establish a baseline
accuracy. In the absence of a formal analysis, it appears

that, since observer #1 changes his attentional allocation according to probabilities, he is at least more optimal in his allocation than observer #2.

A summary of the results is as follows. Observer #1 appears to require more attention for the 75% and 50% conditions than for the 100% condition, but the amount of attention (phi) is equal across 75% and 50% conditions. His attention is differently allocated to cued and uncued locations, between the 75% and the 50% conditions. Observer #2 increased phi as task difficulty increased, and did not appear to be changing his allocation according to probability. There are actually two ways to improve performance in a given task: one is to devote more resources to the task, and the other is to change the allocation of a fixed amount of resources. It appears that observer #1 used both techniques to maintain a given level of performance as task difficulty increased; and, it appears that observer #2 solely increased the amount of resources devoted to the task, as difficulty increased.

CONCLUSION

Given a fixed level of attentional resources, an observer can use probability information to allocate attention optimally. Evidence has also been shown here that an observer might also choose the strategy of allocating more resources to a task, if that course is feasible.

There are some possible problems with certain assumptions made in this experiment. First, allocation of

attention may not be driven purely by stimulus probabilities. The peripheral cues in this experiment may have caused automatic elicitation of attention to cued locations which would serve to artificially increase the attention at the cued location and decrease attention at the non-cued locations. In the next experiment, we will use central cues at the fixation point in order to avoid automatic cuing.

Another consideration is the way the location cuing is conceptualized in this experiment. I have looked at the data in terms of a search (detection) model, whereas it may be more appropriate to view this as a combination detection/identification process. The search model would view detection and subsequent identification as linearly separable stages, while a model for responses based on the accumulation of partial information might describe the process more accurately.

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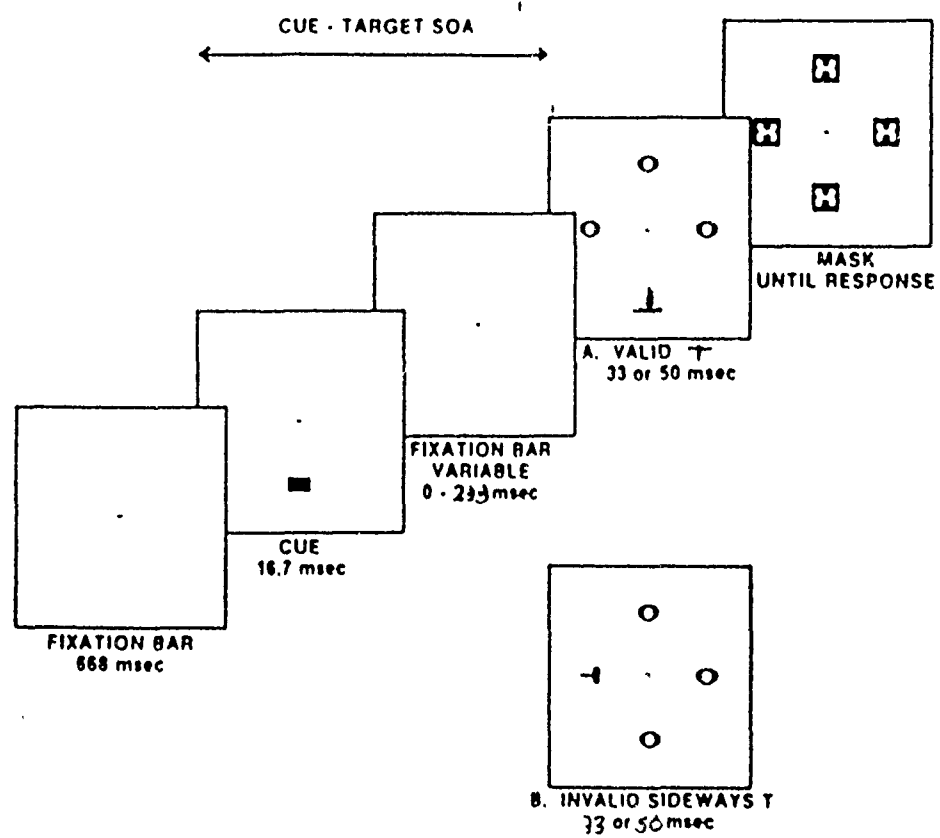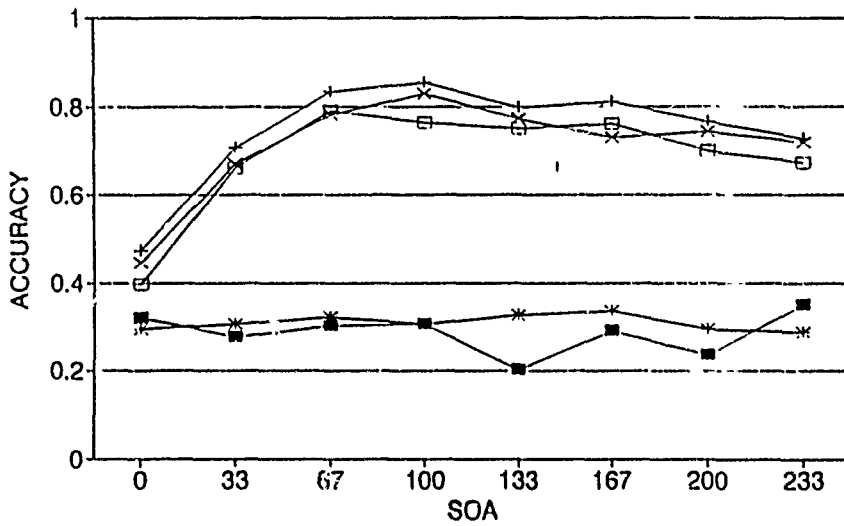
CUE · TARGET SOA

MASK
UNTIL RESPONSE

A. VALID ⊤
33 or 50 msec

FIXATION BAR
VARIABLE
0 · 233 msec

CUE
16.7 msec

FIXATION BAR
668 msec

B. INVALID SIDEWAYS ⊤
33 or 50 msec

FIG. 1. Sequence of stimulus events
FROM CHEAL ET AL., 1991.

16-16

OBSERVER #1

OBSERVER #2
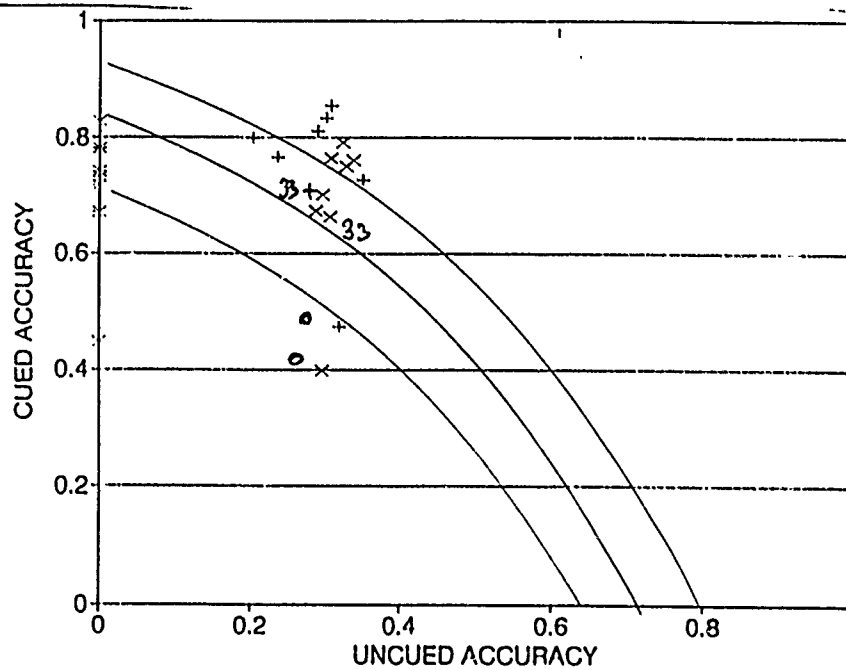

Legend: INV 75, VAL 75, INV 50, VAL 50, 100
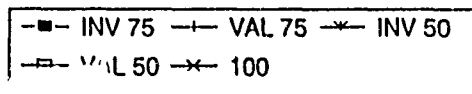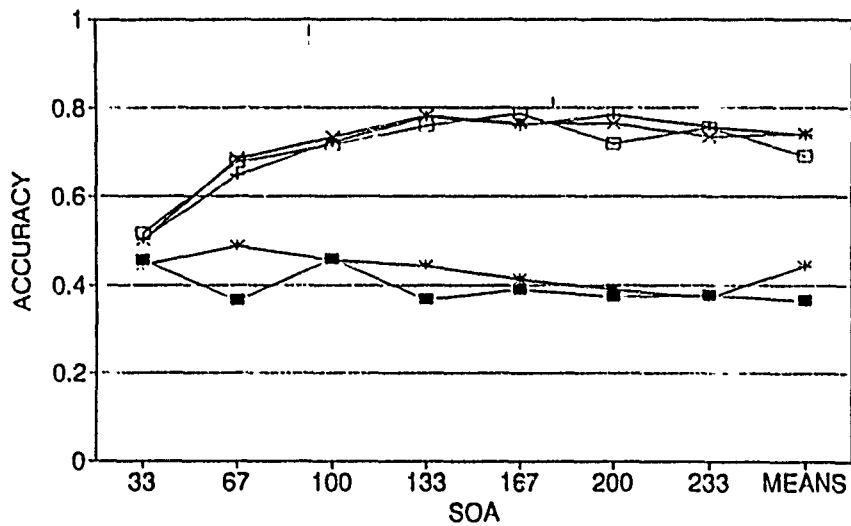
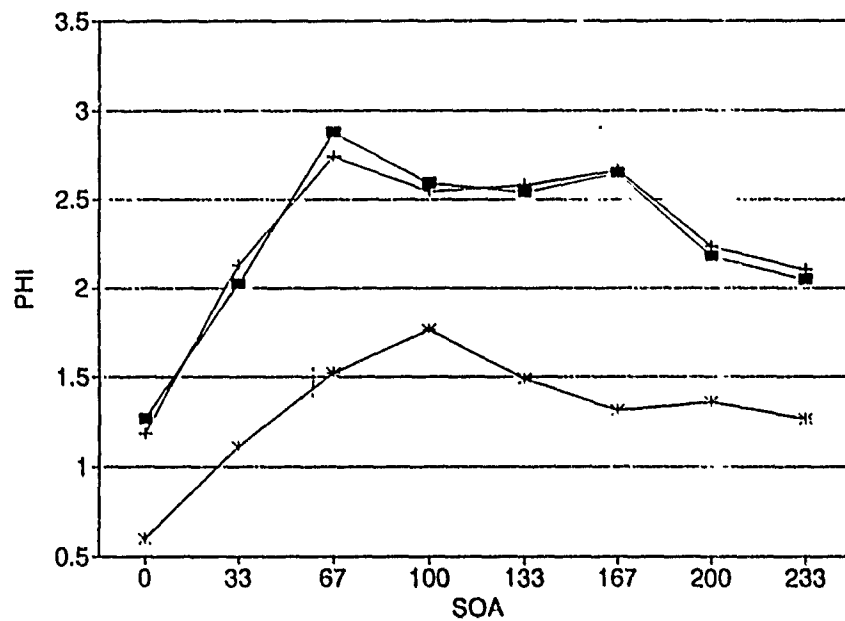FIG. 2. ACCURACY AS A FUNCTION OF SOA.

OBSERVER #1

OBSERVER #2
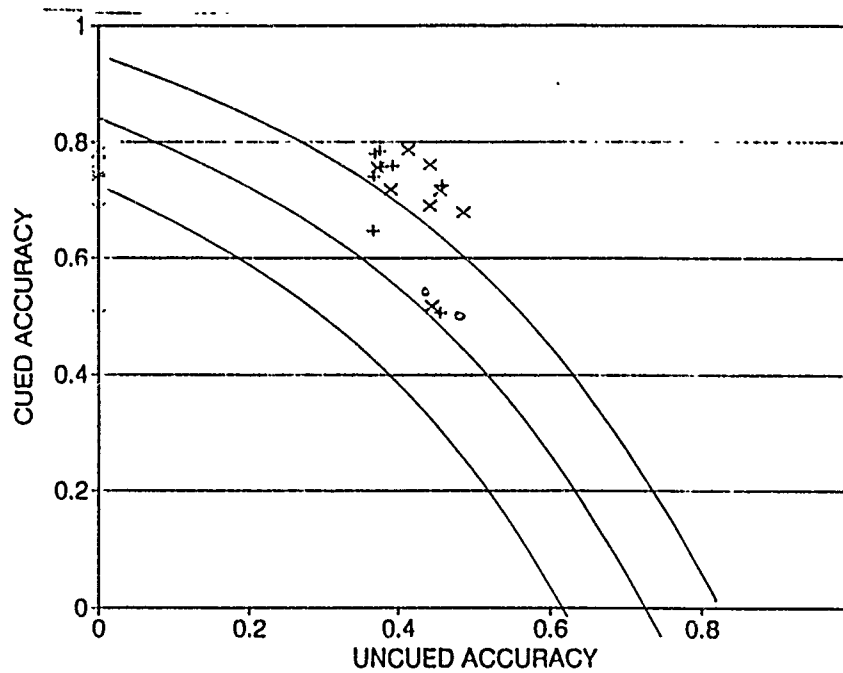
FIG. 3 AOC LOCATIONS AS A FUNCTION OF
CONDITION   ✱ = 100%, + = 75%, X = 50%.
SOME SOA'S ARE INDICATED

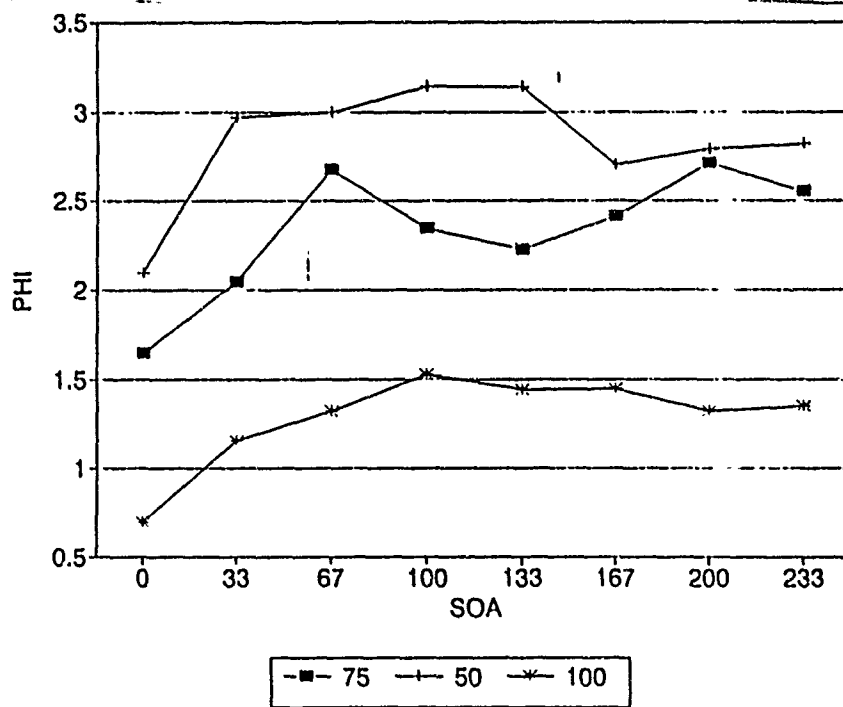# OBSERVER #1

OBSERVER #2

Legend: 75, 50, 100

FIG. 4. PHI AS A FUNCTION OF SOA.

Fundamental Skills and Air Force Accessions: Linking Individual Abilities and Organizational Needs

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Abstract

This paper analyzes data from a wide variety of sources and compiles an inclusive assessment of fundamental skills in the Air Force accession pool. Data from a variety of sources such as The U.S. Census, The U.S. Department of Education, The Department of Defense, The U.S. Air Force, and The U.S. Bureau of Labor Statistics are used to link the material necessary for establishing a general profile of the typical Air Force recruit pool with respect to characteristics associated with fundamental skills and the training of those skills. This demographic information is further coupled with occupational growth patterns, delineating similarities/differences in civilian industries' and the Air Forces' personnel needs. The above information is joined with high school graduation rates and standardized test scores to relate indicators of individual fundamentl skill levels to organizational skill needs. Most data are projected from 1980 through the year 2000, taking into account the impact of any important demographic trends on this process.

Introduction

The role of fundamental skills training assumes greater importance for the U.S. Air Force as military jobs become more technically specialized. Job training programs developed for the purpose of providing well-trained, efficient workers to meet these technical demands require that all individuals involved have a solid foundation in fundamental or basic skills. Inability to complete the necessary training due to a lack of such skills has a direct negative impact on the Air Force mission. Skill deficiencies mean individuals may be unable to effectively perform their jobs and to achieve career advancement. This in turn relates to higher turnover and organizational inefficiency. Several characteristics of the U.S. population directly and importantly affect these processes.

First, demographic trends are a prominent source of information pertinent to issues related to fundamental skills because they define the available recruit pool. Second, changes in the industrial and organizational core affect the types of skills needed to sustain productivity. Finally, education levels and standardized test scores, to some extent, are supposed to identify individual abilities that relate to those skill requirements.

Utilizing data from a variety of sources, our research will attempt to provide a well-documented and inclusive assessment of fundamental skills levels in the primary Air Force recruit pool and link that information directly to Air force personnel requirements. Chart 1 presents our general model of fundamental skills assessment as it relates to the Air Force mission. This research also provides an overview of important sociological insights for creating a working definition of fundamental skills with respect to varying organizational levels within the Air Force.

Defining Fundamental skills

Most attempts to define or evaluate fundamental skills rely heavily on research in the area of cognitive psychology. Initial attempts to systematically review the theoretical and practical definitions of fundamental skills are presented by Schendel, Payne and Mathews (1991):

> The largest differences among the different orientations are in terms of explanatory and predictive power, current heuristic value, and practical value.   ...Cognitive theories, particularly, have shown a clear advantage in terms of their ability to explain why behaviorally-oriented "generic" fundamental skills training programs have been relatively ineffective.

Recent cognitive theories also have had tremendous
heuristic value, both in terms of research they have
fostered and in terms of the many new ideas they have
generated.

This identifies one problem for this analysis: the lack of consensus in

defining fundamental or basic skills. Rese rch in this area offers

valuable insights, particularly with respect to individual level

criteria. However, such a strong concentration on theories and evidence

from cognitive psychology fails to incorporate critical research from

other social sciences such as sociology, anthropology and political

science. The literature from psychology acknowledges the importance of

remembering the impact of social structure on human processes, but

deemphasizes the importance of these structures on individual decisions.

The cognitive psychology approach looks at outcome measures from

individual performances and assumes they reliably and validly identify

fundamental skills capabilities. Documented differences in outcomes

across categories of individuals suggest that structural impacts are

being measured as well. For example, data indicate that at all

education levels, whites outperform African Americans and Hispanics on

standardized tests. These aggregate or structural differences provide a

basis for understanding individual performance variations among Air

Force accession. and linking fundamental skills capabilities to shifting

force demands.

Definitions of fundamental skills are socially constructed,

varying with characteristics of the perceiver, the situational context

and the actors involved. Therefore, information from disciplines such

as sociology becomes critical for developing a more complete

understanding. Definitions of fundamental skills range from the

ability to read, write, and compute in a routine manner, to "higher-order thinking abilities" such as competence in sizing up a situation, making quick and accurate decisions, functioning effectively in new environments and both understanding and communicating the point of what is necessary to complete a task (see, for example, Collino, Aderman and Askov, 1988; Schendel, Payne and Matthews, 1991).

However defined, a plethora of available information supports the growing shortage of and requirement for workers with acceptable levels of fundamental skills[1]. Much of these data are contextual in nature, reflecting the concerns of a specific discipline, industry, organization or skill. For example, in the Air Force, fundamental skills are typically defined with respect to a specific occupational specialty (AFSC). Therefore, the basic skills needed to establish satellite communications links are seen as very different from those needed to perform as a crew chief on a KC-10. This exacerbates the problems associated with defining fundamental skills by making the available information appear scattered and unrelated and underscores the need to organize existing knowledge into a meaningful, comprehensive whole.

TERMS AND METHODS

Population projections for 18 to 24 year olds are derived from the following published tabulations of the Census Bureau's Curent Population Reports: Series P-25 No. 918 (1986) - Hispanic projections; Series P-25 No. 1018 (1989) - White and Black projections; and Series P-20 No. 443 (1990) - high school graduates and college enrollees. All calculations are based on the Bureau's middle series of projections.

The category "white non-Hispanic" was obtained by subtracting the number identified as Hispanic (Spanish Origin) from the number identified as "white", since over 95% of Hispanics are recorded as being of the white race. The "Asian/Other" category was derived by subtracting the "black" and "white" categories from the total projected population. Census Bureau weights were applied to each category in order to correctly calculate the number of non-institutionalized persons.

Projections of high school dropout and college enrollment rates are based on the average percent of change per year from 1980 to 1988 for each racial/ethnic category. In order to keep these estimates conservative, all such calculations were rounded downward. Since data for white non-Hispanics were not available, their graduation and enrollment data are based on the "white" category.

Demographic Trends

Changes in the Labor Pool

Aggregate changes in the demographic profile of the U.S. have important impacts for fundamental skills. The overall population growth rate has slowed primarily associated with the "baby bust" which followed the post World War II "baby boom." The 18 - 24 year old cohort will decrease in size through 1995 (see, Figure 1). Simultaneously, the proportions of African-Americans and Hispanics in this age cohort are expected to increase (see, Figure 2). Women currently comprise a majority of the population, and are expected to remain so at least through the year 2000.

A projected decrease in labor force growth from 2.0% during the period between 1976-88 to about 1.2% between 1988-2000 results from the

above along with a decrease in the high growth rates in labor force participation of women. The projected general slowdown in the growth rate of the labor force will be less extensive for women and racial/ethnic minorities, resulting in a substantial shift in the composition of the labor force.

The labor force of 2000 will include more women and racial/ethnic minorities because their respective growth rates will continue at a faster pace than that of white men and women (see Figure 3). Women comprised 45% of the labor force in 1986 and are projected to increase to 47% by 2000 (Hudson Institute, 1987). Additionally, African-Americans, who made up 11% of the labor force in 1988 will comprise 12% by 2000; Hispanics, 7% in 1988, will increase to 10% by 2000; and Asians and other minorities are expected to increase from 3% in 1988 to 4% by 2000 (Hudson Institute, 1987).

African Americans are the largest U.S. ethnic/minority group, and are increasing in number relative to white, non-Hispanics. Furthermore this group is more likely than others to come from single parent families with resultant socioeconomic difficulties (Figure 4), higher high school drop out rates (Figure 5), and poor health, all of which can negatively impact labor force participation. Labor force participation rates of African Americans are typically lower than other population groups, and they also have higher unemployment rates. Furthermore, those employed are less likely to work in the higher paying technical jobs. This group has historically been an important source of military accessions; members have used the military as a means of attaining political representation and of furthering their socioeconomic status.[2]

Asians and Hispanics are the fastest growing population groups.
Both groups have high immigration rates and come from a wide variety of
countries and cultural backgrounds. While small in numbers, compared to
other minority groups, Asian Americans have the highest levels of high
school graduation, college-attendance, and academic performance. These
individuals also have the lowest unemployment rates. Except for joining
the Navy, Asian Americans have not been likely to participate in
military service.

Hispanics are the youngest of the minority groups in the U.S.,
with a median age in 1987 of 26.1 compared to 31.9 for the population in
general (Mckay, 1988). Hispanics are the currently the second fastest
growing ethnic/minority group. According to Mckay (1988), one in twelve
Americans were Hispanic in 1987, and according to figures distributed by
the Defense Technical Information Center (1984) Hispanics are projected
to comprise 12.1% of the total U.S. population by 2000. This is an
increase of 36.1% from 1980, when they were 8.2% of the total
population. Because of their young median age, the percentages are
higher for younger age cohorts. As early as 1989, Hispanics made up 11%
of 18-24 year old civilians (DoD, 1990). At present, few Hispanics join
the military. According to DoD statistics, only 6% of all accessions,
and 3% of Air Force accessions in FY 1989 were Hispanic. They could
therefore provide a source of previously underutilized Air Force
accessions.

Furthermore, important compositional changes are expected to occur
in the age structure of the labor force. Increases in the relative size
of the 25 - 54 age group should ensue, because the proportion of

employed aged 55 and over is projected to remain relatively constant, while the proportion aged 16 - 24 is expected to decline (see Figure 6). The cohort of 18 - 24 year olds who do not attend college typically are the group from which civilian industries draw entry level recruits. The military enlisted force competes for recruits from this same pool, which is further reduced because the AVF has primarily relied on white, non-Hispanic males within the 18 - 24 age cohort for volunteers (see Figure 7). The college enrollment rate for this group is increasing further reducing the available pool (see Figures 8 and 9). Put simply, the result will be more intense competition for youth among the military, educational institutions and civilian employers, especially for those with high scores on standardized

tests (Chart 2).

Changes in the Labor Market

Recent and projected changes in the labor market continue the shift from goods-producing industries to service industries. By 2000, the service sector is projected to account for 16.7 million of the 18.1 million newly available jobs (Kutscher, 1991). Within this sector, the major occupational groups projected to grow at a faster than average rate are: technical occupations, professional specialty occupations, and executive, administrative and managerial occupations (see Figure 10). The occupations with the slowest projected growth rates include operators, fabricators, skilled crafts, and laborers, while agriculture, forestry and fishing occupations are projected to decline (see, Figure 10).

The fastest growing occupations require the most education and/or training, while those occupations requiring the least education and training either have much slower growth rates, or are projected to decline. This process also holds true for military jobs in general, and the Air Force specialties in particular (see Chart 3). For example, most base maintenance jobs are contracted to civilian workers, while highly skilled jobs such as those in communications systems remain primarily as AFSCs, and the need for these AFSCs is expanding. Increasingly, all services rely on very sophisticated and complex weapons and communications systems to maintain adequate levels of readiness.

These facts combine importantly with the information on the labor pool presented earlier: African Americans and Hispanics are over-represented in occupations having the slowest rates of growth, and requiring the least education and training, while they are under-represented in occupations with the highest growth rates, requiring higher levels of education and training (see Figure 11). An important caution should be interjected here, the seemingly large percentage of ethnic/minorities in the service sector is deceptive. The service sector includes a wide variety of jobs from highly skilled medical technicians to semi-skilled waged laborers such as janitors. The fact that ethnic/ minorities are concentrated in very low-skilled, low-waged jobs within this broad category is easily lost (see Chart 4). This is also the case for women in the labor force (see Figure 12). Moreover, minorities who make up a growing proportion of the 18 - 24 year olds are less likely to go on to college (except for Asian Americans), are more

likely to drop out, complete only associate degrees, or to transfer from two-year community colleges in order to complete their degrees (Mingle, 1987: Chapter 1).

This is exacerbated by higher civilian pay scales, relative to the military, for entry level workers. In other words, that portion of the 18 - 24 year old cohort with superior or sound fundamental skills will be able to demand premium wages in civilian organizations, and as a result be less likely to select the military as a viable post high school option. Burright (1990) notes the difficulties instituting changes to offset these facts:

> The ability and skill gap problem could be eliminated through changes in military compensation policies....New recruits will have to be paid more (emphasis added). Doing so would mean flattening the traditional relationship between earnings and age. The Services would have to pay able recruits more; enlisted bonuses would have to be based on a persons (sic) abilities and skills as well as on military occupation he or she was entering.

Compounding the pay differential, civilian corporations are furnishing training at a variety of levels to employees. New skills, leadership, and literacy are among corporate education offerings. According to Coates, Jarratt and Mahaffie (1990: 273), "almost 20% of companies that provide training teach remedial basic education." Moreover, over the next decade, 4 out of 5 industrial workers will have to upgrade their skills. Given present restructuring of the labor market, a large proportion of the labor force will need to be retrained in new jobs or taught fresh skills. Ford Motor company provides one example (Coates, Jarratt and Mahaffie, 1990: 279):

> * employees receive up to $1500 a year in prepaid tuition at a college or university

* computer awareness, public speaking, goal setting, time management, and rapid reading are types of classes offered in-house
* basic skill-enhancement programs are offered in reading, math and oral communication, leading to high school diplomas or GED certificates
* English-as-second-language (ESL) courses are offered to employees

Sticht and Mikulecky (1984) reported that business such as Equitable Life, Chase Manhattan Bank, General Motors and Continental Bank were already directly addressing basic skills training needs within their organizations seven years ago. These programs have direct consequences for military recruitment.

On the one hand, the military, which advertises itself as a means of gaining needed job skills training, could become an even more attractive alternative employer for minorities unable to compete for jobs in technical and professional specialties. On the other hand, those individuals most likely to join the AVF may lack some of the requisite skills needed to train for today's high-tech military. Moreover, from now on, the military may find that it has to compete directly with civilian firms as a source of technical and job skills training for potential employees.

Educational Impacts

Direct links between education levels of the labor pool and education requirements of the labor market are difficult to establish. Some indicators suggest a general upgrading of the skills necessary to perform at current jobs. Collino, Aderman and Askov (1988) for example, write that "...jobs requiring lower skills will comprise 27% of all new jobs, compared to 40% of current jobs, while 41% of new jobs will

require the highest group of skills compared to only 24% of current

jobs."

And, as Sticht and Mikulecky (1984) argue, while not all jobs will

require more years of training, the technologies required even in jobs

considered low-skilled will require higher levels of basic skills than

in the past. For example, even janitors will be required to use a range

of mechanical equipment which could require reading written instructions

and they may also have to write reports which can be coded into computer

files.

A report issued by The U.S. Department of Education and The U.S.

Department of Labor (1988) highlights the importance of job-related

education and training for jobs of the future. Specifically the report

confirms that:

* The majority of new jobs will require some postsecondary
  education for the first time in history
* Only 27% of all new jobs will fall into low skill
  categories, compared to 40% of jobs today
* Jobs that are in the middle of the skill distribution
  today will be the least skilled occupations of the
  future.

Moreover, the types of reading, writing and analytical tasks

workers perform routinely may be different from those which students are

taught to perform in the school system. For example, students read to

retain information for future use, while workers need immediate "reading

to do" and "reading to assess" skills (see, Huff, Sticht and Joyner,

1977). Training programs for employees are important even beyond the

problems associated with linking skills learned in school to

occupational demands. In the first place, a sizeable proportion of the

high school population drops out before completing their diplomas. And

secondly, 75% of the available labor pool for the next 15 years will have completed their schooling in the present educational system (The Bottom Line..., 1988).

Furthermore, the SCANS Report (1991) outlines the interaction of basic skills such as reading, writing and math with future work requirements. First, employees will have to read and understand a diverse set of descriptive materials including both words and numerical information in order to make decisions and recommendations. Second, most jobs will require the ability to write correspondence, instructions, explanations, illustrations and necessary requests. Additionally, almost all employees will have to maintain records, estimate and evaluate results or apply statistical process controls to inputs. Finally, communications skills including listening to others and articulating one's own perspective demand all of the academic bases described above.

Available data suggest that the projected supply of individuals with even the necessary academic skills could prove problematic. As indicated in Figure 13, while most individuals tested could perform adequately at the lowest level of proficiency, the number achieving proficiency dips rapidly as the difficulty level increases. Mikulecky (1987) identifies basic reading abilities as being able to:

* follow brief written directions
* select words, phrases, or sentences to describe a simple picture
* interpret simple written clues to identify objects
* locate and identify facts from simple informational passages
* combine ideas and make inferences based on short, uncomplicated passages

Above this level of difficulty, reading proficiencies decline rapidly. This decline is particularly evident for African Americans and Hispanics, who tend to have lower standardized test scores (see Figure 14), higher high school drop out rates, and lower socioeconomic statuses than their white, non-Hispanic counterparts. These trends are equally true for math (Figure 15) and science (Figure 16) proficiencies.

Koretz (1990) further illustrates the importance of demographic information for understanding trends in minority education: both age and sex have important impacts on educational attainment and dropout rates independent of minority group membership. His research focuses on African Americans, but underscores the importance of distinguishing subgroups within each minority group for fully understanding trends in minority education. Moreover, Koretz' (1990) analyses raise doubts about the appropriateness of using high school drop out and graduation rates and college enrollment rates alone as indicators of the academic success of minorities. In other words, standardized test results may be confounded by the influence of such factors as amount of spending on education by school districts (see, Harris, 1988).

Using data from a vocabulary test which is part of the General Social Survey, research by Harris (1988) shows that the gap between minorities and white, non-Hispanics increases as level of education increases (see Figure 17). These findings corroborate that of Mingle (1987) who states that, on average, African American and Hispanic 17 year olds read only about as well as 13 year old white, non-Hispanics. Harris' report concludes that any lack in academic preparation, regardless of the reason, compounds over time, and may ultimately lead

to frustration and higher drop out rates (Harris, 1988). Furthermore, this suggests that relying solely on the current education system to solve skill deficiencies will not necessarily accomplish the task.

Women, along with ethnic/minority groups will comprise a growing proportion of the new labor force. As a group, women score slightly better than men on the verbal component of the SAT, but lower than men on the math component (see Figure 18). It is equally true that they outscore men on most portions of the ASVAB, except for the technical portion (Dod, 1984; 1987; 1988; 1990). This suggests that including more women into Air Force accessions will necessitate .raining them in fundamental skills related to technical operations.

As shown earlier at risk groups comprise a growing portion of the labor force and are least likely to have the competencies recently identified by the SCANS Report (1991) as being essential for work place competence. Furthermore research by Ree and Earles (1991) illustrates the absolute loss of potential Air Force accessions who would be likely to rank in the highest AFQT categories based on percentage decreases in aggregate scores. Figure 19 shows the distribution of AFQT Category I and II accessions over time, while Figure 20 illustrates the projected loss of individuals in these highest percentiles. While the AFQT may or may not measure fundamental skill capabilities, it may indicate degree of familiarity with the cultural context important for success in military job performance (see, Ree and Earles, 1990; Teachout and Pellum, 1991). If AFQT scores are related to job performance and if maintaining high levels of technical competence is important for the Air Force, then the decline in Category I and II accessions could have

deleterious consequences for accomplishing the Air Force mission. In other words, "Air Force training activities will have to train less able and skilled people to do more complex jobs with fewer resources (Burright, 1990)."

A MODEL OF THE AIR FORCE ACCESSION POOL

Figure 21 illustrates our model of the Air Force accession pool relative to the 18 - 24 year old age cohort in the U.S. Note that at first appearance, demographic projections of the youth cohort (Figure 22) suggest that the Air Force would not have a problem maintaining necessary force strength. In particular, the decrease in the white, non-Hispanic males, between the ages of 18- 24 (the primary Air Force accession pool) is expected to turn around after 1995. However, if we factor in other demographic information, which we know will impact the availability of new recruits, we see a dramatically different trend (see Figure 23). The model was created using Lotus 1-2-3, which allowed us to subtract trend information for categories unlikely to be available for voluntary Air Force service from the initial recruit pool. Our estimates are conservative ones, because all trends and averages used were rounded down, and because global catalysts, which could create sudden need for increased personnel (such as another Operation Desert Storm), were not factored into our equation.

Once high school drop outs and college attendance rates are factored in, the result is a decreasing available accession pool through the year 2000 (see Figure 24). The shift in the distribution suggests an increasing proportion of African Americans relative to white, non-Hispanics because of combined increasing high school graduation and

decreasing college attendance rates. Once again this is a conservative estimate, not accounting for increased competition from the civilian labor force, decreasing numbers scoring at higher percentiles of the AFQT, nor differential minority/sex inclinations to enlist.

In order to maintain necessary strength, during periods without a major conflict, it appears the Air Force will have to recruit from non-traditional groups. Barring the return to a draft military, another major conflict will necessitate reliance on a non-traditional recruit pool. This non-traditional recruit pool will have to include a higher representation of minorities, who tend to score lower on standardized tests, and women, who tend to score lower on mathematical and technical aptitude tests. Individuals who have dropped out of high school, or those scoring in the lower percentiles of the AFQT may also have to be considered. In either event, fundamental skills will be important for new accessions into an operational, efficient Air Force.

CONCLUSIONS

This report presents a strong demographic argument for why the fundamental skills project is important to the performance of the Air Force mission (see Figures 21 through 24). The data reported highlight the shrinking pool of young workers (ages 18-24), particularly white, non-Hispanic males. This results in a reduced Air Force accession pool, especially in combination with:

* increasing college attendance rates for those with higher academic skills
* current higher school drop out rates
* lower standardized test scores for minorities (except for Asian Americans)
* decreasing numbers scoring above Category IIIa on the AFQT.

Competition with the civilian labor force for well educated and technically skilled workers will increase as service sector as well as professional, technical and administrative jobs expand and manufacturing, agriculture, and skilled crafts and semi-skilled laborers, requiring little formal education decrease in importance. Overall poor performance on standardized tests, along with gaps in scores between Hispanics, African Americans and white, non-Hispanics suggests problems with relying on the present education system to supply workers with requisite fundamental skills. While the U.S. education system may reach a large proportion of the population, the academic preparation provided may be inadequate. Restructuring of the work place due to changes in technologies and communications may have redefined the types of skills needed for adequate job performance. Skills critical to the future work force may be in short supply. As presented by the SCANS report, such skills will include the ability to interpret as well as absorb information presented in the form of both words and numbers. To counter problems with entry level employees' lack of fundamental skills, many corporations are providing remedial basic training. This further magnifies the competition for entry level workers between civilian industries and the military, which has traditionally provided additional training and education to individuals needing and desiring them.

As Air Force jobs become more technically specialized, job training programs become even more important than ever for successful completion of the Air Force mission. Advanced training programs developed to provide highly skilled, efficient workers require a solid

foundation in fundamental skills. Skill deficiencies lead to the inability to perform adequately on the job or in required training programs. Not only will this create ineffective operations at all levels of the Air Force, it can also lead to individual frustrations because of blocked career advancement, with serious adverse consequences for morale and the overall sense of esprit de corp needed to maintain the tradition of excellence in today's Air force. These forces impact minority subgroups more strongly than white, non-Hispanics. The net result is an Air Force that is neither cost effective nor representative of the population it serves.

IMPLICATIONS FOR FUTURE RESEARCH

This report was written as supporting documentation for a proposed larger research effort. The goal of the additional research will be to ascertain any predictive capability of ASVAB scores for assessing Air Force relevant fundamental skills. The definition of and indicators of fundamental skills used will be those generated by researchers from HAY Systems, Inc., who are in the process of completing the definition task. If the second portion of the task can not be completed, other available standardized aptitude and job performance measures will be used for the analysis.

Specifically this research will use regression models as a means of controlling for structural impacts (ie., race/ethnicity, sex, age, education level) related to individual performance. For example, if race and sex account for differences in skill performance indicators independent of ASVAB scores, this would suggest that such scores may not be valid predictors of fundamental skills capabilities.

1. See Coates, Jarratt and Mahaffie for a comprehensive presentation of demographic forces and skill levels which are "reshaping work and the work force in North America."

2. See, Janowitz, 1976 for a discussion of the military as an avenue for underprivileged groups to improve their education and skills.

3. For references see 'JUANITA M. FIRESTONE' vol. 2

The Efficacy of Multimedia Instruction.

For

Air Force Office of Scientific Research
in care of
Research Development Laboratories
Culver City, California

By

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ABSTRACT

A review of literature was conducted to determine if there is support for the belief that multimedia presentations influence learning and to identify the criteria necessary for a multimedia presentation to facilitate learning. Based on the findings of research involving linear and nonlinear multimedia as well as comments about research conducted, it is suggested that a multimedia presentation can influence learning. Such presentations should get students to mentally process information presented. Research in areas (Dual coding theory, Multiple resource theory, Transfer, Attributions and Modeling) that contribute to the effective design of multimedia presentations are discussed.

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THE EFFICACY OF MULTIMEDIA INSTRUCTION

Mark J. Gavora
Research Associate

INTRODUCTION

The term multimedia has been used for several decades and has a variety of definitions associated with it. In the broadest sense, multimedia is a construct that refers to the combination of audio, video, graphics and text used for communication. Examples of multimedia presentations include:

♦ Pictures with corresponding text in books.

♦ Slide Shows synchronized with tape presentations.

♦ The use of posters, radio and television to advertise a product.

♦ Using a computer to simulate a driving environment in order to train students how to drive.

For this paper, the term _multimedia_ will be restricted to refer to only those media that support motion video. A more general term that is often used in place of multimedia is the term _media_ which does not necessarily imply the use of more than one symbolic code (audio, video, text or graphics) for communication.

There are a number of ways to categorize multimedia presentations. One way is to categorize the presentations based on how they present data-- Linearly versus nonlinearly. A linear multimedia presentation (Figure 1) has a starting
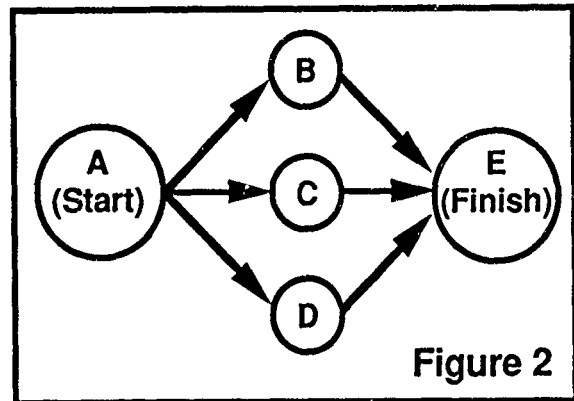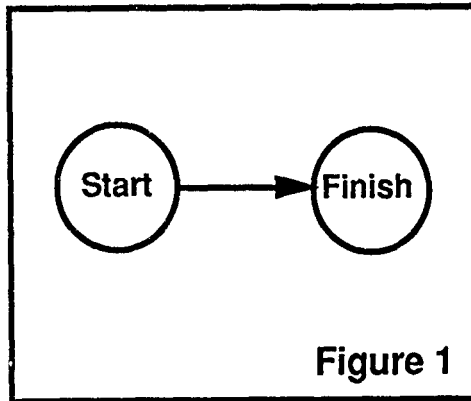
Figure 1

Figure 2

point and an ending point and presents information from start to finish along a single path. Examples of linear multimedia technologies include film, instructional television and videotape. A nonlinear multimedia presentation (Figure 2) has a starting point and an ending point but does not present information from start to finish along a single path; instead, progress may proceed through a number of paths. In figure 2, for example, the individual can move from segment A to segments B, C or D then to E. Examples of nonlinear multimedia technology include presentations on compact disk, videodisc, and to a lesser degree, videotape. The interruption of the normal sequential flow of a presentation, characteristic of nonlinear multimedia presentations, is referred to as branching. If we were to play the presentation illustrated in figure 2 sequentially, the segments would probably be located side by side on the storage medium. The resulting presentation would be in the format illustrated by figure 3.

Figure 3
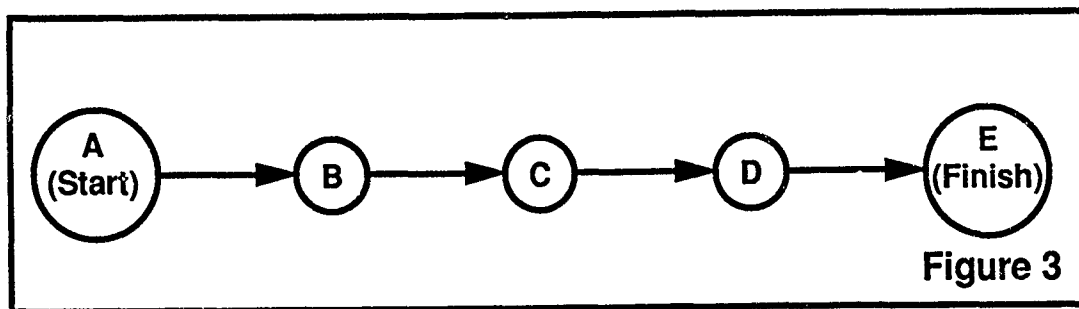
ANALOG MULTIMEDIA PRESENTATIONS

The advantage of a multimedia approach in relation to more conventional educational approaches is that the multimedia approach utilizes more than one sensory domain (sight and sound) for communicating information allowing students to experience and process events to a greater extent than afforded by books or verbal explanations. In addition to seeing pictures and hearing sounds, students have the opportunity to witness interactions that could not otherwise be realistically replicated in a conventional classroom. Multimedia technology also allows educational techniques such as lectures to be transmitted to a variety of locations through satellite or repeated at different times and locations through videotape.

Based on these characteristics, educational institutions and the military have considered multimedia presentations beneficial for two reasons:

1. They facilitate learning.

2. They reduce the cost of educating students especially those in remote locations.

Rose (1976) examined thirteen instructional technologies used by the department of defense. These included computer and audiovisual technology, instructional television, cable television, satellite communication and CAI (Computer assisted instruction). He concluded that the appropriate combination of these technologies and the pooling of resources and delivery systems would enhance the quality of personnel and reduce cost. More recently, Jenkins (1990) claimed that children learn through the use of their senses, and this multisensory learning was more compatible with, hence facilitated by, multimedia instruction.

LINEAR

Before computers, multimedia based educational programs incorporating motion video could only be delivered through film or broadcast through television. Instruction was presented in a linear fashion and could only be paused for a predefined duration or stopped (film). The introduction of videotape increased the flexibility of delivery systems allowing segments of the presentation to be rewound an replayed or skipped by fast forwarding. Although basic interactivity in the form of branching was, at best, limited and cumbersome, educators quickly adopted this approach.

Subsequent research on the efficacy of linear multimedia

instruction incorporating motion video, has yielded mixed results. In a review of research on instructional media, Jamison, Suppes and Wells (1974) maintained that instructional television did not differ significantly in effectiveness from more conventional instructional paradigms. Clark (1983), after examining research on the efficacy of media based classes, not only concluded there were no differences in achievement attributable to media, but also recommended that "...researchers refrain from producing additional studies exploring the relationship between media and learning unless a novel theory is suggested."

Other researchers have not gone so far as to discount absolutely the effectiveness of multimedia instruction. Rose (1976) expected videodisc technology to address the problems inherent in earlier forms of multimedia presentations by permitting random access and switching to other modes of presentation (i.e. computers). Kulik, Kulik and Cohen (1980) performed a meta-analysis on research dealing with various instructional technologies including audio and video based training. They concluded that these technologies produced positive results; however, these results were not "large" and would be barely perceptable in typical classes. Kozma (1991) described televised presentations as transient and identified two problems associated with transient presentations:

1. They are not sensitive to the cognitive constraints of the learner; instead, they progress regardless of comprehension.

2. The viewer cannot review data already presented.

He also stated that transient information may be useful in building the dynamic properties of mental models. Finally, he explained how computers, interactive video and hypermedia can be successfully used to facilitate learning. Learning across these three media is influenced, in part, through interaction between the user and the system controlling the media.

Salomon (1976, 1979) claimed that changing the technology used to present instruction neither influences nor should influence learning. He, instead, attributed differences in learning to the symbolic code of the message. Symbolic codes are sets of units (points, alphanumerics, frequencies, colors etc.) that are combined or used to represent information. Salomon and Clark (1977) distinguished between research with and research on media. According to them, research with media involves comparisons based solely on the modes of presentation, while research on media involves creative utilizations of the media and their affects on learning. By focusing on psychological effects rather than appearance, issues such as information processing are addressed.

NONLINEAR

Research suggests that for learning to be facilitated, a multimedia presentation must be designed to encourage the

processing of the data being presented. One way this can be achieved is by making the presentation interactive. Although VCRs can display data randomly without the aid of a computer, students would be required to position the tape to certain LED positions competing for cognitive resources, and most likely, restricting the processing of data. The work involved would be too cumbersome to be feasible. Alternatively, a computer could control an analog device (i.e. videodisc).

Generally there are two advantages of nonlinear presentations over linear presentations. The first advantage is that a nonlinear technology offers more opportunities for interactivity. Through a computer, the capabilities cited by Rose for videodiscs are made available not only for videodisc presentations, but for videotape presentations as well. Branching is supported through some form of menu-driven interface often creatively designed to minimize the look and feel of text-based, menu-driven interfaces. Mode switching is automatically controlled and is transparent to the user. The second advantage is that, for many projects requiring interactivity, a nonlinear presentation is easier to implement than the equivalent linear presentation. This is largely a result of the first advantage. Because interactivity was minimal with linear multimedia technologies, branching could only be simulated through the use of multiple devices (i.e. projectors) controlled by an individual monitoring the instruction; furthermore, the instruction would have to be

synchronized. This helped to insure that a response was quickly accompanied by an appropriate segment of instruction.

Subsequent research regarding analog multimedia instruction has yielded positive results. Kulik, Bangert and Williams (1983) performed a meta-analysis examining the influences of CBI (computer-based instruction) including simulations which involved audio, graphics and text. They found that CBI relative to conventional instruction resulted in increased performance while reducing the time it took for students to learn the material. Nugent (1987) examined several studies on the efficacy of videodisc based training and concluded that videodisc based instruction resulted in lower study times and equal or better ~ .formance.

RESEARCH RELATF~ TO MULTIMEDIA

DUAL CODE THEORY

Paivio's dual code theory rests on the premise that information can be stored in a semantic or imagery format (Paivio, 1971). The semantic format represents meaning (i.e. Chimpanzees are bipeds). The imagery format represents visual data. Best (1989) described the imagery format as the elements of a stimulus that are represented by the nervous system in a way that preserves many of the relationships observed among those elements in the natural world. These representations are not necessarily duplicates of visual stimuli; however, they retain properties similar to visual stimuli (i.e. shape, size, detail etc). According to Paivio,

memory will function better when both representations can be crossreferenced.

Research on Dual Code theory has yielded positive results. Shepard and Metzler (1971) found that the time it takes for a person to identify an object as being the same or different from a reference object is directly proportional to the angular disparity between the two objects. Such a relationship should not exist unless people were rotating an image of the objects mentally; hence, this research supports the idea of an analog representation in memory. More recently, Amlund, Gaffney and Kulhavy (1985) had students look at a map of the island of Ako and listen to a taped presentation about its people. They found that subjects recalled more information involving features from the map than information not involving features from the map. They concluded that had subjects used a unitary coding system, recall would have been the same for feature and nonfeature information; consequently, a dual coding system must have been in use.

Support for Paivio's dual coding theory adds credibility to the idea that multimedia presentations facilitate learning. If, as his theory suggests, memory does function better when imagery and verbal representations can be crossreferenced, then multimedia presentations provide an avenue for both representations to be formed. More research is necessary to determine the extent that multimedia presentations facilitate

the development of these representations relative to more conventional presentations (i.e. pictures in books).

MULTIPLE RESOURCE THEORY

Multiple resource theory is a relatively new concept that functions as an alternative explanation to central capacity theories for task interference (Navon and Gopher, 1979). The idea of multiple resources was expressed by Norman and Bobrow. According to them, all mental processes demand a certain amount of cognitive resources and can compete with other mental processes for those resources (1975). Every person has a limited supply of resources available to process stimuli and perform tasks. Performance degradations occur to the extent that the processing of tasks and stimuli compete for the same resources. Multiple resource theories differ from central capacity theories in that central capacity theories treat indifferently the resources available to a person for processing data; consequently, performance degradations occur to the extent that processes compete for resources.

Research on multiple resource theory has focused on determining the extent that the theory is valid while expanding our understanding of it. Wickens and Liu (1988) found that the degree of performance degradation at one task was reduced when another task performed simultaneously did not involve the same processing codes (i.e. an auditory and a visual code). They stated that interference will increase as more levels across the three dimensions that were initially

proposed by Wickens (1980)-- early versus late processing stages, auditory versus visual processing modalities and verbal versus spatial processing codes-- are shared by two tasks. Hirst and Kalmar (1987) identified three models of multiple res' 'rces including the one proposed by Wickens. Their research suggests that an integration of existing models may be necessary to better account for experimental results.

Multiple resource theory offers a very direct explanation of how multimedia presentations can produce greater knowledge gains in relation to conventional presentations. Through presenting information across a variety of media, competition for limited resources across a single dimension is reduced; therefore, performance decrements resulting from cognitive overload would be minimized. This theory, however, is an emerging theory and has not been developed to the extent that the other theories explained in this section have. Until more research has been conducted, applications of multimedia design based on multiple resource theory should be conservative.

TRANSFER

Transfer was studied by Thorndike and Woodworth as early as in 1901. It refers to the ac· ivation and application of knowledge to new situations (Gagné, 1985). Transfer differs from learning in that learning involves consistently activating and applying a specific knowledge set upon exposure to a particular stimulus based on experience. The stimulus or situation does not need to be new. While all learning

involves transfer at some trivial level (Salomon and Perkins, 1989), transfer is distinguished from learning by the degree that a new situation is novel. An example of learning is when a student studying Spanish is provided with a list of English words and their Spanish equivalents which he memorizes. The next day the teacher requires him to write the Spanish equivalent for several English words on the list given out the previous day. If the student answers correctly, he has learned the words. An example of transfer is when a student, aware of several rules for arithmetic, is given a problem whose solution requires him to combine the rules. If the student correctly solves the problem, transfer has occurred.

There is an abundant amount of research dealing with transfer. Today, research focuses on the dynamics of transfer rather than whether transfer occurs. Gagné and White (1978) reviewed research dealing with memory and learning. They assert that transfer of knowledge is facilitated by the degree of interrelationship between propositions, intellectual skills, images and episodes. Salomon and Perkins (1989) identify two types of transfer: High-road transfer and Low-road transfer. Low-road transfer is facilitated by "automatic, stimulus-controlled and extensively practiced behaviors or cognitions." High-road transfer is facilitated by "mindful deliberate processes that decontextualize the cognitive elements which are candidates for transfer."

There are many ways that multimedia instruction could

facilitate learning through transfer. One way is through the number of cues that multimedia provides. Multimedia presentations offer a continuous array of audio, video and textual information which can be combined to form rich knowledge structures. Any combination of stimuli in the real world may activate relevant associations involving these structures resulting in the person using that knowledge to aid performance. Multimedia technology also allows realistic simulations to be developed, affording the opportunity for students to practice at various tasks. This opportunity for practice should facilitate low-road transfer as explained by Salomon and Perkins. Realistic simulations also reduce the distance of transfer, further facilitating transfer.

ATTRIBUTIONS

There is an abundant amount of research dealing with the influence of perceptions on task selection, effort invested and overall performance. Much of this research has involved perceived self-efficacy, outcome expectancies, perceived demand characteristics and locus of causality. Perceived self-efficacy refers to an individuals confidence in the ability to successfully perform tasks at a given level (Shell, Murphy and Bruning, 1989). Outcome expectancies are beliefs about contingent relations between successful task performance and perceived outcomes (Shell et. al., 1989). Perceived demand characteristics are inferences made by an individual about the requirements of a task. Locus of causality refers

to the beliefs about ones success or failure. The common idea behind these theories is that behavior is influenced by the perceptions of the individual regarding a stimulus and not by the actual characteristics of the stimulus.

Of particular interest to multimedia instructional designers is the research regarding behaviors resulting from a student's perceptions of a medium. Salomon (1984) found that children attributed successful comprehension of televised presentations to external sources but attributed successful comprehension of text presentations to internal sources. He also found a correlation between perceived self-efficacy and amount of invested mental effort and between attributed realism (an indicator of perceived demand characteristics) and invested mental effort. He maintained that children who scored high in perceived self-efficacy perceived the task of televised learning as "easy;" consequently, they invested less mental effort in the learning task.

The notion that the way an individual perceives a stimuli or event can influence mental processing has important implications for the design of instruction. Salomon's findings suggest that we need to persuade students to perceive multimedia presentations in such a way that encourages them to increase the amount of invested mental effort used to process the information. Multimedia instruction could also be used to influence the development of perceptions regarding the various tasks that students are being trained to perform. Students

could learn how to perform a task, perceive the task as interesting and enjoy successful task performance.

MODELING

Modeling, as proposed by Bandura, refers to the ability of individuals to learn a behavior or attitude without direct reinforcement. An example of modeling is when a child, who has watched another child in a film receive praise for turning off the lights after leaving a room, begins to turn lights off after leaving a room. Modeling is intimately related to social learning theory and vicarious conditioning. The degree that modeling is effective depends, in part, on the similarity between the model and the observer and the nature of rein-forcement given to the model for performing a behavior. Bandura (1969) argued that all learning involving direct reinforcement could also result from observation.

A classic study that is regularly cited in support of modeling is an earlier experiment performed by Bandura, Ross and Ross (1961). They found that children exposed to an adult displaying aggression toward a Bobo doll resulted in later acts of aggression against the doll. These acts of aggression were often the same acts and vocalizations used by the model rather than random acts of aggression. They, later, found that modeling via television was just as effective as modeling via a live model (Bandura, Ross and Ross 1963). More recent-ly, Schunk and Gunn (1985) have found modeling which emphasiz-es the importance of task strategies increases a student's

skill at performing a task and degree of perceived self-efficacy. Perceived self-efficacy is greatest when the model also emphasizes achievement beliefs.

A multimedia presentation can provide an avenue through which modeling can be easily supported. In addition to showing people how to behave in certain situations, instructional designers can structure these presentations to increase students' perceived self-efficacy and other self-concept components (Bandura and Gunn's research provide reason to suspect that components of ones's self-concept other than perceived self-efficacy might also be influenced by modeling). More research is needed to identify the extent that modeling influences learning and motivation.

SUMMARY AND CONCLUSIONS

Multimedia refers to the combination of audio, video graphics and text used for communication. In addition to utilizing more than one sensory domain for communicating information, multimedia can reduce the cost of education through distance learning.

Early forms of multimedia presentations could only be displayed linearly. Although virtual branching could be supported through multiple devices, it wasn't until the development of the videotape that branching could technically be supported. Branching by videotape, however, was a slow process. Effective branching didn't become available until videodiscs were developed. Computer based analog nonlinear

multimedia technology supported branching and mode switching which greatly increased the capability of multimedia presentations to influence learning.

Research dealing with linear multimedia instruction has produced mixed results. Several reviews of experiments dealing with the efficacy of media have found that the majority of these experiments report no significant difference between media based presentations and more conventional presentations. Research dealing with analog multimedia instruction has produced more positive results.

There are many areas of research related to multimedia development and implementation. These include dual code theory, multiple resource theory, transfer, attributions and modeling. Dual code theory suggests that memory will function better when imagery and verbal representations can be referenced. Multiple resource theory proposes the existence of a set of resources and postulates that performance degradations will occur to the extent that tasks and stimuli compete for the same resources. Transfer suggests that multimedia instruction is effective to the extent that it provides cues to facilitate encoding, categorization and retrieval. Research involving attributions remind us to consider the students perceptions of the presentation and the task. Lastly, modeling provides multimedia designers with a technique to develop perceptions and facilitate learning.

Overall, multimedia instruction is an effective approach to educating students. Even linear multimedia instruction, which often failed to enhance learning, has been able to reduce the cost of educating students without hindering learning. The failure of experiments involving such instruction to increase learning in relation to more traditional techniques could be the result of two errors. First, as explained by Salomon (1976) the multimedia presentations could be failing to offer anything new. One would not expect students to learn more from watching a lecture on television than from being present at the actual lecture. Second, the opportunity for a student to refer to previous words, sentences paragraphs and chapters at will when reading a textual description is not available with linear multimedia; however, linear multimedia potentially provides a variety of stimuli to learn from and maximizes the cognitive resources one can allocate to the presentation. The benefits between the two techniques may have a canceling effect. Future research involving multimedia technology and its influence on learning should identify the characteristics of the technology that account for the greatest variance in learning and propose models for the design of effective multimedia presentations.

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COMPARISON OF BACILLUS ANTHRACIS AND BACILLUS CEREUS DNA USING PULSED FIELD ELECTROPHORESIS

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Research Associate

ABSTRACT

Pulsed field electrophoresis (PF), a method that permits resolution of larr DNA fragments (3-50 megabases)(2,7), was used to compare the analogies between Bacillus anthracis (BA) and Bacillus cereus (BC) DNA banding patterns.

BA and BC were grown in nutrient broth and 3AT media (nutrient broth, nitrate, luminol and 3AT) for 24 hours or 6 days. DNA was extracted from the cells and digested with restriction enzymes(RE). Digested and undigested DNA were run in the pulsed field gel. Gels were photographed and DNA photos were compared.

INTRODUCTION

BA and BC are interrelated in terms of their mutability and spore form-
ing ability(1). When grown in 3AT media BA tends to assume a particular shape
and brown color that last for a period of time before the cells lyse. This
indicates the formation of diazoluminomelanir '' .M)in the cell. BC, which
was used as a negative control, assumes the or .y rod shape and the change
in color is not quite as distinct as in BA. Given the variability in color
and shape between BA and BC, the aim of this experiment is to study differ-
ences in DNA band pattern of cells grown with or without 3AT medium and be-
tween BA and BC using pulsed field electrophoresis.

Nitrate is the major compound for nitrogen acquisition in nature(5,6).
The first enzyme of the nitrate assimilacory pathway, nitate reductase, cata-
lyzes the reduction of nitrate to nitrite and is subject to tight control at
the levels of enzyme activity, synthesis, and degradation(3). BA has a very
active nitrate reductase gene, while BC does not. The nitrate reductase gene
in this bacteria enhance the production of DALM which is know to be sens'.cive
to microwaves. If the nitrate reductase is isolated from the BA and used to
transform mammalian cells it may be useful in cancer research. If the trans-
formed cells produce DALM and are irradiated with microwaves, the DALM produc-
ing cells will be killed without damaging non DALM-containing cells.

Pulsed field electrophoresis (PF) is useful for the study of very large
pieces of DNA(2,7). Conventional eletrophoresis does not permit resolution of
DNA fragments larger than 3 kilobase pairs(10). By alternating the electric
field between spatially distinct pairs of electrodes, DNA in the order of ten

megabase is able to reorient and move differentially through the pores in an agarose gel(7,14). The key to high resolution, sharp bands, straight lanes, and reproducible separation is a uniform electric field at all points of a gel, and an optimal 120 degrees angles of alternating pulse(4). BA and BC DNA were run for 15 hours,60 seconds switch time for electrodes at 200V, followed by 8 hours , 90 seconds at 200V(10).

BA and BC that were grown in 3AT media were later extracted by chloroform method. DNA samples were run in the PF gel in order to determine the size of the DNA and compare it.

Restriction enzymes are part of a group of endonucleases or enzymes that cut phosphodiester bonds of polynucleotide chains at internal bonds(8,11,12,13). Restrictions enzymes recognize specific sequences of poly-nucleotides(12,15). RE, which were used to digest BA and BC DNA were EcoR., EcoRV, MspI, HpaII, PstI and BamHI. Cut and uncut DNA were compared after been run in the pulsed field.

MATERIALS AND METHODS

Bacterial strain-Strains of Bacillus cereus and Bacillus anthracis were grown in 8g/L nutrient broth or 2X 3AT media (8g/L nutrient broth, 12g/L nitrate, 100g/L luminol and 80g/L 3-amino-L-typosine) at 37°C and 200 rpm for 24 hours or six days.

DNA extractions- After growth BA and BC were spun at 4°C and 8,000 rpm. The cell pellet was dissolved in 15 ml of lysis buffer solution (0.32M sucrose, 10mM tris HCl pH 7.5, 5mM MgCl$_2$ and 1% Triton X-100 at 4°C) and left on ice for 15 minutes. The lysed cells were centrifuged at room temperature at 2,700 rpm in order to obtain a nuclear pellet. To the nuclear pellet 0.075M NaCl, 0.024M EDTA pH 8.0, 5% SDS and 10mg/ml protein K solution were added. The solution was allowed allowed to incubate at 37°C overnight. After incubation, 5 ml phenol equilibrated with 20mM tris HCl pH 8.0 solution and 5 ml of 24:1 chloroform/Amyl Alcohol solution were added. After gentle shaking the solution was centrifuged and the upper layer of the liquid were placed in a clean tube, 5 ml chloroform was added, and the mixture shaken and recentrifuged. To the upper layer 1/10 volume of 3M Sodium Acetate (NaOAc) and 2.2 volume of cold Ethanol (ETOH) were added and DNA obtained by inverting tubes back and forth till DNA spooled. The spooled DNA was dissolved in DNA Buffer solution. When DNA failed to spool after chloroform extraction, it was placed in -20°C refrigerator overnight and ultracentrifuged the next day at 4°C, 20,000 rpm for 20 minutes to obtain DNA pelleting.

DNA Digests-DNA was digested with 1mg/ml BSA, 10mM DTT, 1X Digestion Buffer and Restriction Enzymes(8,9). Digests were incubated for an hour at

$37^{o}C$. Digested DNA was precipitated to concentrate the DNA before running in gels. After digestion the DNA was pelleted by Ethanol precipitation using 1/10 volume of 3M NaOAc and 2.2 volume of ETOH, and allowed to sit in $-70^{o}C$ for an hour and centrifuged to obtain pellets. Pellet were allowed to dry and DNA Buffer was added.

Pulsed Field Electrophoresis-0.5X TBE Buffer and 1% agarose gel were used for electrophoresis. Gels were run at $14^{o}C$ for 15 hours, 60 seconds switch time at 200V followed by 8 hours running time, 90 seconds switch time at 200V(4). DNA fragments between 3 to 50 kilobases were run at $10^{o}C$, 170 V, 12.5 hours and 1second switch time(7).

Photography-Polaroid MP4 Land camera was used to photograph the gels. Pulsed field gels were treated for 30 minutes with 0.5mg/ml Ethidium Bromide (Fluorescent dye), rinsed with distilled water and exposed to ultraviolet light and photographed. Photographs were used to compare the DNA patterns.

RESULTS

DNA digested with BamHI and PStI showed a better pattern of bands than with any other restriction enzymes. Many small bands were observed in BA and BC.

Size of undigested DNA in relation to the standard DNA, which was lambda/hind III, have an approximate range of 30 KB in the DNA treated with nutrient broth and 28-25 KB in the DNA grown in 3AT media for 24 hours or six days (figures 1 and 2).

There is a visible difference in the banding patterns which may indicate that the DALM produced in the cells is causing change.

Differences in the size of undigested DNA and bands patterns of digested DNA is appear to be more distinct in BA, than in BC (figures 1 and 2).
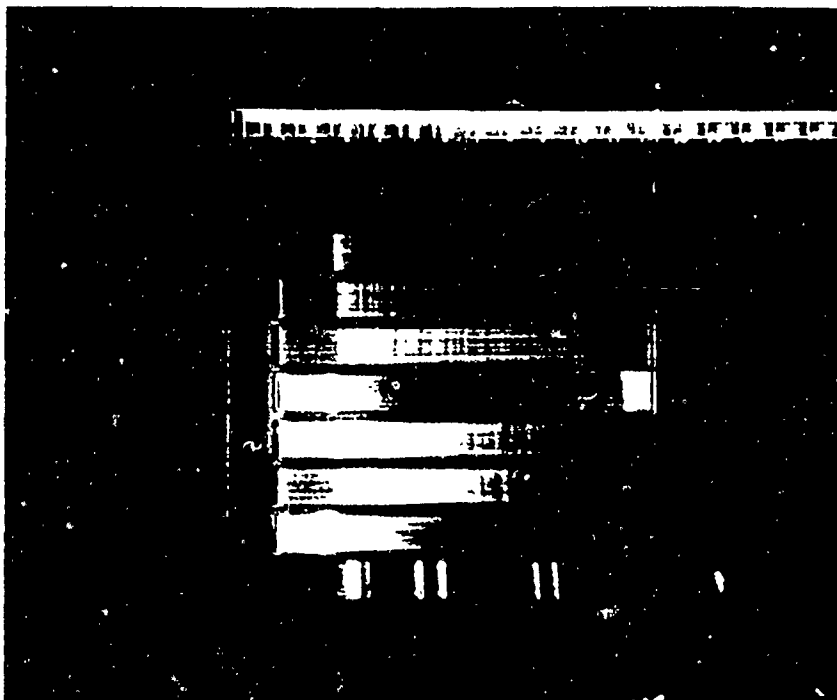
Figure 1. BA DNA ran in a pulsed field electrophoresis agarose gel for 12.5 hours,1 second switch time at 170V at 10°C. Lambda DNA was the standard. BA grown in nutrient agar and 3AT media for 24 hours and 6 days were digested with BamHI and PstI. Digested and undigested were compare in terms of DNA size and banding patterns. Bottom to top: lambda, undigested BA grown in nutrient broth for 24 hours, BA (24hours/nutrient broth) digested with PstI, BA (24 hours/nutrient broth) digested with BamHI, undigested BA grown for 24 hours in 3AT media, BA (24 hours/3AT) digested with PstI, BA (24hours/3AT) digested with BamHI, undigested BA grown for 6 days in 3AT media, BA (6days/3AT) digested with PstI, BA (6days/3AT) digested with BamHI.
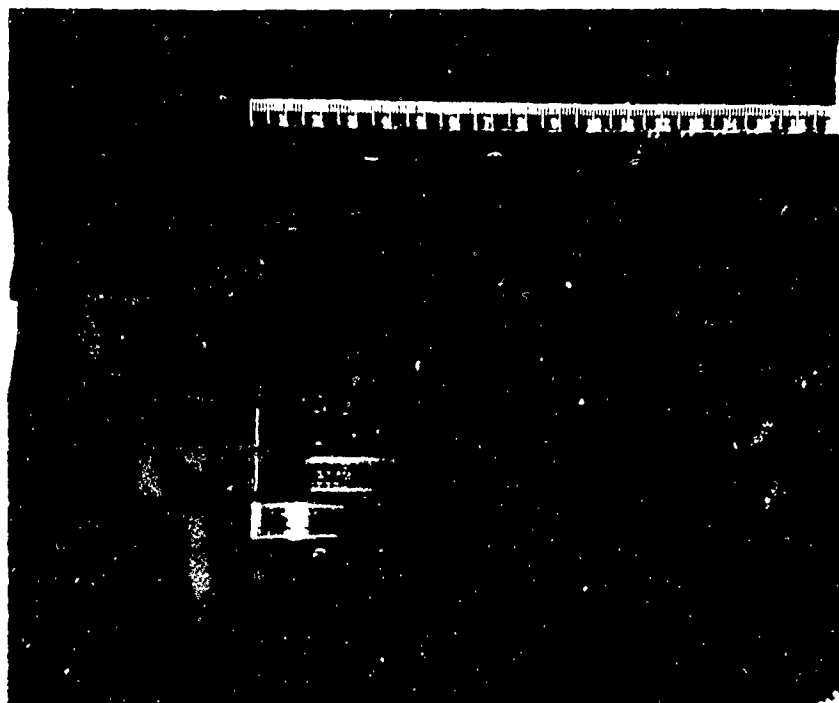
Figure 2. BC DNA ran in the pulsed field electrophoresis run under the same parameters as in figure 1. Bottom to top:
Lambda DNA (standard), undigested BC grown for 24 hours in nutrient broth, BC (24hours/nutrient broth) digested with PstI, BC (24hours/nutrient broth) digested BamHI, undigested BC grown for 24 hours in 3AT media, BC (24hours/3AT) digested with PstI, BC (24hours/3AT) digested with BamHI, undigested BC grown for 6 days in 3AT media, BC (6days/3AT) digested with PstI, BC (6days/3AT) digested with BamHI.

CONCLUSIONS

Given the differences in size of uncut DNA and the banding patterns of cut or digested DNA it is obvious that the DALM being produced in the cells was causing change in the DNA, but is not destroying it.

Further progress toward other aspects in BA and BC DNA may be interesting to explore such as to what part, if any, of the DNA does the DALM attach, or perhaps, identify the specific nucletides or nucleotide sequences to which the DALM may attach.

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IMPROVING THE WORK OF THE HAZARDOUS WASTE BRANCH OF ARMSTRONG LABORATORY

by

Dion D. Farrell

ABSTRACT

The Hazardous Waste Branch of Armstrong Laboratory is responsible for monitoring environmental quality through contract negotiations necessary to accomplish field work. My job was to assist in the contract formatting and to aid in several other projects. These tasks were successfully completed and thus furthered the mission of the branch.

INTRODUCTION

This internship was completed at the Air Quality & Hazardous Waste Branch (OEBQ) of the Bioenvironmental Engineering Division (OEB) of the Occupational and Environmental Health Directorate (OE) at Brooks AFB, Texas. The Hazardous Waste Branch mission is to monitor the environmental quality for the United States Air Force (USAF) of different air bases and Department of Defense (DOD) installations and design contracts for the testing, assessment, and remediation of Underground Storage Tank (UST) sites. I was used in the capacity of assisting with contract formatting, the development of Statement of Works (SOW) and functioned in other areas which aided in the division's functions.

OBJECTIVES

The main purpose for the summer was to assist in the
production of SOW's and to compile the present SOW's into a
folder of hard copies for easy accessibility. SOW's are
documents which format job(s) to be done at a respective air
base or DOD installation, such as Camp Stanley and Ft. Sam
Houston, Texas. These documents cover such jobs as
environmental assessments, UST site assessments, preserveys, and
other areas which involve compliance with the environmental
standards of the United States Environmental Protection Agency's
(USEPA) Resource, Conservation and Recovery Act (RCRA).

The second project was to provide support in the issuing
of contracts. When a SOW is completed, it must be sent to
contracting to be obligated in order for work to begin.

The third project was to assist in the preparation of a
UST seminar. This seminar is to instruct and inform over one
hundred DOD personal in handling UST.

DISCUSSION

As stated earlier, the Hazardous Waste Branch monitors the
environmental quality of different installations. When field
work is necessary, a SOW is written to inform the contractor of
tasks that need to be done. The SOW is a set of guidelines
that must be followed by the contractor doing the work. It
provides background information on the installation, what the
problem may be and what kind of work the installation wants

done. The SOW also outlines to the contractor other information such as government supplied items, documents and security clearance needed, and the point of contact (POC), usually at Armstrong Lab (AL) and one at the installation where work is being done. At the end of each SOW, deadlines are stated with reference to technical and assessment reports. Any analytical work needed is specified in tables at the end of the SOW. The finished SOW is then sent to the contracting department for a formal contract to be drawn up and obligated with funds so the job can be done. An example of an SOW is given. It is a site assessment of suspected leaking of three UST's at Galena Airport in Alaska.

When writing a SOW, the author usually refers to previous SOW's that are similar to the one being written. These previous SOW's were scattered either through out the branch or on the computer under individuals personal files. What was needed was a way of getting all of these documents together in one place so it would be easier to get hold of one for reference. It was decided to put together a folder which would hold all the hard copies of these SOW's with a reference number of where each could be found in the computer. The computer reference of these SOW's were also assembled on the computer in a specific file called EC_GENERIC, under its own folder named, appropriately, SOWS. This made it convenient for everyone who needed to find a SOW in the computer for reference. The cover sheet for the

compilation folder is attached at the end of the report.

The putting together of this compilation SOW book helped the department in many ways. In one way, it cuts down on the amount of time spent on drawing up new SOW's and modifying previous ones. For example, if one were to draw up a new SOW, it could take about a week to complete it, maybe two weeks, and because other SOW's are usually found in everyone's personal file in the computer, there is no way of referring to previous SOW's that might be similar to the one being written. Also, no one in the department really has the time to commit to searching for the information. With the SOW book at hand, one can easily reference the SOW they need and can finish it in less than a week. As for modifying a previous SOW, instead of having to type the SOW over again, the previous SOW can be brought up on the computer and the changes are made there. All modifications and new SOW's are added to the SOW book, thus keeping it up to date.

The SOW book is helpful also in the fact that everybody can use it. It not only gives previous and up to date SOW's, it gives a format of how the SOW should be written so that it can be easily understood by the contracting office. Everyone in this department and the other two departments, Air Quality and Water Quality, started using it the day I finished putting it together, so it was much needed.

There was a growing need in the DOD community for

information on UST's. UST's are commonly used in many installations but the knowledge needed to.comply with regulations was only found in select groups at different air bases. The decision was made by Capt. Pat McMullin to offer a UST seminar to introduce to the DOD personnel the information needed to handle UST's. A lot of the work done to arrange and set up the seminar was done by another graduate student aid, Karen Somers. I was asked to aid in arranging the schedule for the seminar and some of the leg work. In arranging the schedule, I was to produce a flier which would contain the seminar topics and information needed to attended the seminar. When first I arrived at Brooks, I was given some training on Harvard Graphics (HG) which was to be useful in my work here. The work done on the flier was done on HG. The flier is attached to this report. So far, the seminar had been a success in that at least 90 had signed at the time this report was written and it is expected to grow to well over one hundred DOD personnel.

The seminar contains ten topics which is to be covered in a two day period. The seminar is being presented free of charge by Armstrong Laboratory. The presenters have also offered their services free of charge. The presenters represent both public and private industries, contractors, and academic institutions, such as USEPA, University of Texas San Antonio (UTSA), and the Army Corps of Engineering. Two of the ten topics, Accessing the OED On-Call Contractors for UST Support and Case

Histories/Scenarios, will be done by Lt. Nancy Miller of the Hazardous Waste Branch of Armstrong Laboratory.

ACCOMPLISHMENTS

The objectives given at the beginning of this report were successfully met by the end my ten weeks here. The UST seminar is dated for the 20th and 21st of August, but I will not be here to attend.

CONCLUSION

As stated above, all the projects that were attempted at the beginning of the summer were completed be summer's end. It was an enjoyable and learning experience at Brooks AFB. I really appreciate the assistance I received from Capt. Pat McMullen and TSGT Mark Bishop with the job and my stay here in San Antonio. The people in the branch were very helpful and we had a good working relationship. I thank them for there help.

STATEMENT OF WORK

SITE ASSESSMENT

GALENA AIRPORT, ALASKA

1. DESCRIPTION OF WORK

1.1 Background

1.1.1 Galena Airport is located in Galena, Alaska. Underground storage tanks (UST) 37, 38, and 49 are suspected to be leaking. These tanks were inoculated with DDM tracer as part of a leak detection monitoring system installed in Jan 91. The probes placed as part of the leak detection system detected the DDM tracer outside the tanks in sufficient quantity to declare these tanks to be leaking in excess of .05 gallons per hour. These tanks did not fail any inventory test conducted in the past (+/- 0.5%). Tank 37 is a 1.05 million gallon diesel fuel tank, Tank 38 is a 1.05 million gallon JP-4 tank, and Tank 49 is a 12,000 gallon diesel fuel tank.

1.1.2 This statement of work outlines requirements for assessing the environmental impact (if any) of the suspected leaking tanks. The assessment will include, but is not limited to, installation of groundwater monitoring wells, performing soil boring, collecting groundwater samples and analyzing those samples for petroleum hydrocarbons and the tracer elements used in the inoculation.

1.2 Scope

The contractor shall provide all services and supplies to perform detailed sampling, analysis, and evaluation of the three USTs in accordance with applicable State and Federal regulations. Methods and procedures required are specified in paragraph 1.4.

1.3 General Compliance and Applicable Documents

Guidance and requirements shall be drawn from applicable government regulations and industry and regulatory guidance documents. These documents are referenced in the following subsections.

1.3.1. Applicable Regulations

1.3.1.1 Requirements for site remediation at Galena Airport will be obtained from the following State and Federal regulations

-- Alaska Department of Environmental Conservation and Board of Storage Tank Assistance, Title 18, Alaska Administrative Code, chapter 78, Underground Storage Tanks, March 1, 1991.

-- U.S. Environmental Protection Agency, Title 40 (Protection of

Environment), Code of Federal Regulations, Parts 280 and 281, Underground Storage Tanks, July 1, 1989 (promulgated under authority provided in RCRA).

-- Occupational Health and Safety Administration, Title 29, Code of Federal Regulations, part 1910.120, July 1, 1989.

1.3.2 Industry and Regulatory Guidance Documents

Guidance in areas not specified in the regulations will be obtained from the personal experience of contractor UST experts and from guidance documents which are listed below.

-- A Guidance to the Assessment and Remediation of Underground Releases, API publication 1628, second edition, August 1989.

-- Alaska Department of Environmental Conservation, Guidance for Storage, Remediation, or Disposal of Contaminated Soils, February 8, 1991.

1.4 Task and Technical Requirements

1.4.1 Inspections and Records

The contractor shall designate a Field Team Leader (FTL) to remain on the job site during all field activities. FTL oversight is especially important during sampling and analysis efforts. The FTL shall ensure that all phases of the field work are in compliance with appropriate regulations, job specifications, and safety requirements, and shall document and photograph all phases of the borehole and monitoring well installation. A detailed log of the conditions and materials penetrated during the borehole and monitoring well installation shall be maintained by the hydrogeologist/geologist on site. The field team leader shall coordinate and interface with ADEC inspectors, government project managers, and other authorities during the course of field activities.

1.4.2 Borehole Drilling

A maximum of 6 boreholes shall be installed not to exceed a total of 200 linear feet. The borings shall be inspected by visual and olfactory means for signs of tank leakage. An organic vapor analyzer such as an (OVA) equipped with a flame ionization detector (FID) or an HNu equipped with a photoionization detector shall be used to measure head space total organic vapors present in the borings. A maximum of 15 soil samples shall be collected and analyzed for parameters listed in Table 1. All drilling augers and sampling equipment will be decontaminated using a steam cleaner and mild phosphate free detergent prior to drilling. All sampling equipment will be decontaminated prior to each sampling event.

1.4.2.1 Borehole Log

For each borehole, prepare a borehole log showing a continuous

description of lithologies of drill cuttings and how the borehole was constructed. Include boring logs in the Monitoring Well and Borehole Report.

1.4.2.2 Precautions

Consult with the base POC and the tank operator to properly position the boreholes with respect to site locations, and to avoid underground utilities. A utilities map shall be consulted before any boring activities take place.

1.4.2.3 Air Monitoring During Drilling

Monitor the ambient air during all soil boring work with a photoionization meter or equivalent organic vapor detector to identify the generation of potentially hazardous and/or toxic vapors or gases. Include air monitoring results in the boring logs. If soil encountered during borehole drilling or test pit work is suspected to be hazardous because of abnormal discoloration, odor or air monitoring levels, containerize the soil cuttings in drums and prepare a manifest for base documentation. Enter into the boring logs the depth(s) for which suspected contaminated soil cuttings were collected.

1.4.2.4 Sealing Boreholes

Tremie grout the borehole to the surface with a bentonite/cement slurry. Boreholes must be adequately resealed to preclude future migration of contaminants (if present).

1.4.2.5 Marking Borehole Locations

Permanently mark each soil boring location. Record the location on a project map for each specific site or zone, whichever is applicable. Include project map in the Monitoring Well and Borehole Report.

1.4.3 Monitoring Well Installation

Monitoring wells shall be drilled using hollow-stem auger techniques and installed in accordance with ADEC regulations. A maximum of 10 wells shall be installed not to exceed a total of 300 linear feet. A maximum of 25 water and 10 soil samples shall be collected from these wells and analyzed for parameters listed in Table 1. Monitoring well installation protocol is described in the statements below.

1.4.3.1 Well Drilling

Drill all wells using a 10 1/2-inch hollow-stem auger. Avoid installing wells in depressions or areas subject to frequent flooding and standing water. If wells must be installed in such areas, design the wells such that standing water does not leak into the top of the casing or cascade down the annular space. All drilling augers and sampling equipment will be decontaminated using a steam cleaner and mild phosphate free detergent prior to drilling. All sampling equipment will be decontaminated prior to each sampling event.

1.4.3.2 Well casing requirements

Construct each shallow well with 4-inch Schedule 40 PVC casing. Use threaded screw-type joints only. Glued fittings are not permitted. Flush-thread all connections.

1.4.3.3 Well depth

Install wells five feet below the water table as determined by the on-site hydrogeologist/geologist.

1.4.3.4 Well Screening

Screen each shallow well using PVC casing having up to 0.010 inch slots. Each well screen shall be a maximum of ten (10) feet in length. Cap the bottom of the screen with a threaded PVC cap. Screen all wells so as to collect floating contaminants and to allow for yearly fluctuations of the water table. Once the casing is in place, install the sand/gravel pack. The sand/gravel pack will consist of washed and bagged rounded silica sand or gravel with a grain size distribution compatible with the screen and soil formation. Place the pack from the bottom of the borehole to two (2) to three (3) feet above the top of the screen. A two-foot bentonite seal (granular or pellets) will be placed above the sand/gravel pack. Ensure that the bentonite forms a complete seal by hydrating the bentonite with a sufficient quantity of potable water. Grout the remainder of the annulus to the land surface with a Type I Portland cement/bentonite slurry.

1.4.3.5 Well Completion

Complete the well flush with the land surface. Cut the casing two to three inches below land surface, and install a protective locking lid consisting of a cast-iron valve box assembly. The valve box will be placed in the center of the hole with the top just above the ground surface. Concrete will be placed around the annular space and sloped away from the valve box to divert drainage. Also, provide a watertight compression casing cap to prevent infiltration of surface water. Maintain clearance between the casing top and the bottom of the valve box. Clearly mark the well number on the valve box lid and well casing. Provide locks for the well assemblies. The locks must either have identical keys or be keyed for opening with one master key. Turn over the lock keys to the post POC following completion of the field effort.

1.4.3.6 Well Log

For each well, prepare a well log/well schematic showing how the well was constructed.

1.4.3.7 Well Development

Develop each well as soon as practical after well completion with a submersible pump, bailer, and/or airlift method. Continue well development until the discharge water is clear and free of sediment to the fullest

extent possible as determined by the on-site hydrogeologist/geologist. Measure the rate of water production, the pH, specific conductance, and water temperature during well development. All development water will be drummed and left on-site for disposal by Galena Airport.

1.4.3.8 Water Level Measurements

Measure water levels at all monitoring wells as feet below the top of casing elevation to the nearest 0.01 foot. Measure static water levels in wells prior to well development and before all well purging which precedes sampling events.

1.4.3.9 Precautions

Consult with post personnel to minimize disruption of installation activities, to properly position wells with respect to site locations, and to avoid underground utilities. A utilities map shall be consulted before any drilling or boring activities take place. Borehole locations will be coordinated with Galena Airport personnel prior to commencement of the field work.

1.4.3.10 Cleanup

All well borehole cuttings will be drummed and left on-site for disposal by Galena Airport.

1.5 Reports and Plans

The following reports and plans shall be prepared by the contractor:

1.5.1 Health and Safety Plan

A Health and Safety plan shall be developed in accordance with 29 CFR 1910.120. This plan shall define emergency procedures, discuss any hazards that could be encountered during site preparation, address accident prevention, and present appropriate action levels for any contaminant likely to be encountered.

1.5.2 Monitoring Well And Borehole Report

The contractor shall prepare and submit a detailed report documenting field activities associated with borehole and monitoring well installation The report shall contain a detailed log of the conditions and materials penetrated during the borehole and monitoring well installation, laboratory analyses of soil and water, conclusions made from the borehole and monitoring well installation and analytical results, notification documents, and chain of custody documents. Based on findings of the site assessment, accomplish an ADEC approved "No Further Action Document," or provide recommendation for remediating and closing the site.

1.6 Miscellaneous Requirements

The site assessment is to be coordinated with the Alaska Department of Environmental Conservation (ADEC), 5099 CEOS/DEEP, and 5072 CSS/DE.

2. SITE LOCATION

Galena Airport
Galena, Alaska

3. BASE SUPPORT

Galena Airport shall support contractor activities by providing the following:

-- Access to the site during daylight hours, Monday through Saturday, while work is in progress.

-- Emergency response points of contact.

-- Locations of underground utilities at the site (preferably marked on the ground surface).

-- Base Personnel will assist contactor in determining safe placement of boreholes and monitoring wells.

4. GOVERNMENT-FURNISHED PROPERTY

None

5. GOVERNMENT POINTS OF CONTACT (POC)

ARMSTRONG LABORATORY (AL)
Capt. Patrick McMullen
AL/OE2E
Brooks AFB, Texas 78235
(512) 536-3305
FAX 512-536-3945

GALENA
Capt. Ken Brown
5509 CEOS/DEEP
Elmendorf AFB, Alaska 99506
(317) 552-4854
FAX 317-552-5849

6. DELIVERABLES

   Documents. In addition to sequence numbers 1 and 5 listed to attachment
1 to the basic contract, which apply to all orders, the sequence numbers
and dates below are applicable to this order:

Seq.		para	Block 10	Block 11	Block 12	Block 13	Block 14
4	H&S PLAN	1.5.1	OTIME	7DAC	8DAC	N/A	4*
4	Mon Well Rpt	1.5.2	ONE/R	90DAC	91DAC	150DAC	4*

* one copy to the AL POC and 3 remainder to the Galena POC.

TABLE 1. LABORATORY ANALYSES

Parameter	US EPA Method	# of Samples
BTEX (soil)	8020	25
TPH (soil)	418.1	25
BTEX (water)	8020	25
TPH (water)	418.1	25

COMPILATION BOOK
STATEMENT OF WORK (SOW)
HARD COPIES

BIOENVIRONMENTAL ENGINEERING DIVISION
OCCUPATIONAL ENVIRONMENTAL HEALTH DIRECTORATE
BROOKS AFB, TEXAS 78235-5501

UNITED STATE AIR FORCE
ARMSTRONG LABORATORY (AFSC)

UNDERGROUND STORAGE TANKS (UST) SEMINAR

Offered by the Bioenvironmental Engineering Division of Armstrong Laboratory

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Review of Regulations
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  - Overview and Conclusions
- OSHA Requirements for UST Remediation

UST Management Plan
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  - Existing tanks
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- UST Management and Control Plan

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Accessing the OED On-Call Contractors for UST Support
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Case Histories/Scenarios
by AL/OEB

To register for seminar call Karen D. Somers DSN 240-3305, commercial (512) 53.-3305.

UNDERGROUND STORAGE TANKS (UST) REGULATIONS AND COMPLIANCE PROCEDURES

Research Associate
Karen Dennis Somers

Abstract

The Hazardous Waste Management Division of the Bioenvironmental Engineering Division of the Occupational and Environmental Health Directorate (formerly Armstrong Laboratory) provides environmental consultants to the US Air Force on a variety of projects involving compliance and remediation. One of the rapidly growing areas concerns USTs. The focus of my research was three-fold. First, I researched the regulations, methodologies and technologies concerned with USTs. Second, I created, organized, and conducted a comprehensive DOD seminar on USTs. Third, I served as project manager for several government contracts on sites involving USTs, as well as other hazardous waste remediation and clean up projects.

Introduction

President Reagan signed into law on November 8, 1984, the Hazardous and Solid Waste Amendments. This law, which reauthorizes and amends the Resouce Conservation and Recovery Act (RCRA), added a new Subtitle I to the federal hazardous waste statute. Subtitle I of RCRA requires the Environmental

Protection Agency (EPA) to develop a comprehensive regulatory
program to prevent, detect, and correct releases from certain
USTs storing regulated substances- petroleum and hazardous
substances, including chemicals. The law also encourages
states to develop and substitute, with EPA approval, their own
UST regulatory programs that are no less stringent that the
federal rules.

On July 14 1986, EPA proposed final hazardous waste
standards applicable to accumulation tank systems, interim
status tank systems, and permitted tanks systems. These
regulations were codified as 40 CFR Parts 264 and 265, Subpart
J, and became effective on January 12, 1987. The regulations
covered by this Subpart apply to tank systems used for
treatment or storage of hazardous wastes. Included are
aboveground, onground, and underground tank systems.

On September 23, 1988 EPA proposed final standards
applicalbe to underground storage tanks. These regulations,
condified as 40 CFR Parts 280 and 281, contain technical
requirements and state program approval.

Discussion

The Department of Defense must comply with the
aforementioned regulations. The DOD constitutes one of the
largest owners of USTs. It has become an enormous task to
educate and train individuals responsible for bringing the
millions of Air Force UST systems into compliance. The office
at Brooks Air Force Base through their contract support role

has found itself increasingly involved in UST work. As a response to the need for rapid eduction and training this office decided to sponsor a seminar devoted to UST technologies and methodologies. In order to offer the best possible training the subject area had to be researched. Also, the practical aspect of contract management had to be experienced.

Underground Storage Tanks

Anyone owning a UST must have a Management Plan in place. Elements of this plan are dictated by whether the tanks are existing or new tanks and whether they contain petroleum or hazardous wastes (defined by CERCLA 302.4). The plan must outline actions which are prioritized with regard to the age and condition of the tank. All tanks must be tested for leaks. There is a variety of methods for performing leak tests and new methods are being investigated as well as old methods improved. Lead detection is now a mandatory part of the upgrading of old tanks and installation of new tanks. Again there is a large variety of acceptable methods.

If a leak is detected a whole set of actions are set in motion. First, the leak must be contained and cleaned up immediately, that is the tank emptied and any free product removed. If the amount of substance has exceded the federal limits then the release must be reported and a corrective action plan filed with the implementing agency.

In the initial abatement stage persisting health and safety hazards must be mitigated, vapor threats and otential leaking of contaminates posed by excavated or exposed soils must be remedied. If any soil is excavated it must be disposed of as required. Reporting of the progress of initial abatement must be reported. Remediation of the site due to a large spill may require one cf more remediation technologies. For the remediation of groundwater there exists air stripping or a variety if types, activated carbon absorption, biorestoration or a combination of types. To remediate soil, air stripping and biorestoration can be applied. If the soil is not in large quantity it is often removed to a solid waste landfill. Also incineration is used for the disposal of contaminated soil.

To chose the correct remediation technologies the following factors must be examined: aquifer characteristics, influent concentration, discharge requirements, contaminant properties, surface conditions/constraints, and other site conditions.

The final stage is to perform a site closure. In order to declare a site closed the tank must either be removed (and disposed of as required) or closed in place (emptied, cleaned and filled with approved filler). The implementing agency must be notified at least 30 days prior to closure and a site assessment must be performed. The site assessment involves one or more of the following: vapor monitoring, ground-water monitoring and sampling during removal. One the site is

closed, closure records and site assessment results must be maintained for three years. Factors which affect the closure option are state and local regulations, technical feasibility, anticipated environmental conditions, expense and the policy of the owner.

Please find attached a Statement of Work that examplifies the work done this summer. To write this statement of work knowledge of federal and state regulations was required, a general technical background was applied and negotiation skills were utilized to communicate the needs of the customer (Camp Stanley) to the contractor.

STATEMENT OF WORK

SITE ASSESSMENT AND COMPLIANCE PLAN
CAMP STANLEY, BOERNE TX

1. DESCRIPTION OF WORK

1.1 Background. Camp Stanley is an U.S. Army installation located in Boerne, Texas. The underground storage tank (UST) system at Camp Stanley consists of 22 USTs. The tanks range in capacity from 500 gallons to 24000 gallons. Eight tanks are used to store diesel, gasoline, and solvents and fourteen tanks were used to store heating oil but are no longer in service.

1.2 Scope

The contractor shall provide all services and supplies to perform a regulatory assessment of the 22 USTs and a subsurface contaminant assessment at eight of the locations. The regulatory assessment will involve tank site inspection, tank location and site mapping, and determining the feasibility of registering the fourteen heating oil tanks. All UST work will be performed in accordance with applicable State and Federal regulations. Methods and procedures required are specified in paragraph 1.4.

1.3 General Compliance and Applicable Documents

Guidance and requirements shall be drawn from applicable government regulations and industry and regulatory guidance documents. These documents are referenced in the following subsections.

1.3.1. Applicable Regulations

1.3.1.1 Requirements for site assessment, USTs inventory preparation, sampling and analysis, and preparation of compliance plans at Camp Stanley will be obtained from the following State and Federal regulations:

-- Texas Water Commission, Title 31, Texas Administrative Code, chapter 334, Underground and Aboveground Storage Tanks, January 26, 1990.

-- U.S. Environmental Protection Agency, Title 40 (Protection of Environment), Code of Federal Regulations, Parts 280 and 281, Underground Storage Tanks, July 1, 1989 (promulgated under authority provided in RCRA).

-- Occupational Health and Safety Administration, Title 29, Code of Federal Regulations, part 1910.120, July 1, 1989.

1.3.1.2 Texas Water Commission (TWC) UST Rules are as stringent or more stringent than U.S. EPA UST rules. TWC rules are enforced in the State of Texas by the TWC.

1.3.2 Industry and Regulatory Guidance Documents

Guidance in area not specified in the regulations will be obtained from the personal experience of contractor UST experts and from guidance documents which are listed below.

-- A Guidance to the Assessment and Remediation of Underground Releases, API publication 1628, second edition, August 1989.

-- Texas Water Commission, Guidance Manual of LPST Cleanup in Texas, Petroleum Storage Tank Division, January 1990.

-- Removal and Disposal of Underground Petroleum Storage Tanks, API recommended practice 1604, second edition, December 1987.

1.4 Task and Technical Requirements

1.4.1 UST Regulatory Assessment. The contractor shall obtain and review records and other pertinent information on the UST system at Camp Stanley. This effort shall assess the current UST status and the regulatory requirements for installation, maintenance, and upgrading of Camp Stanley's UST system. Recommendations and relative cost estimate options shall be prepared. All information shall be presented in the UST Assessment Report.

1.4.1.1. Records Review. The contractor shall obtain and review records and other pertinent information available on the existing USTs.

1.4.1.2 Tank Inspection. The contractor shall conduct an inspection of each of the 22 UST sites and take photographs of each site for documentation. During each inspection the contractor shall use visual and olfactory means for signs of tank leakage.

1.4.1.3 Inventory Preparation. The contractor shall take the information obtained during the Records Review (Para 1.4.1.1) and the Tank Inspection (Para 1.4.1.2) and prepare it in tabular form.

1.4.1.4 Tank Registration. The contractor shall determine the feasibility of registering the fourteen (14) small tanks.

1.4.2 UST Mapping. The maps described below shall be included in the UST Regulatory Assessment Report.

1.4.2.1 General UST Site Map. The contractor shall prepare a general site location map showing the locations of all USTs.

1.4.2.2 Area Geologic Map. The contractor shall provide a geologic map of the local area.

1.4.2.3 Individual UST Site Maps. The contractor shall prepare individual site maps and drawings.

1.4.3 Subsurface Investigation

1.4.3.1 Borehole Drilling. The contractor shall conduct a borehole survey consisting of a maximum forty borings, approximately 5 borings at each of the eight (8) large (1000-gallon to 24000-gallon capacity) UST sites. The borings shall be inspected by visual and olfactory means for signs of tank leakage. Qualitative indications of the presence of volatile organic compounds present in soil or rock at the site subsurface will be obtained by performing head space analysis on samples retrieved from borings using an organic vapor analyzer such as an (OVA) equipped with a flame ionization detector (FID) or an HNu equipped with a photoionization detector. One or two samples from each boring shall be selected on the basis of head space analysis and analyzed for parameters listed in Table 1. All drilling augers and sampling equipment will be decontaminated using a steam cleaner and mild phosphate free detergent prior to drilling of each hole. All sampling equipment will be decontaminated prior to each sampling event.

1.4.3.2 Borehole Log. For each borehole, the contractor shall prepare a borehole log showing a continuous description of the subsurface lithologies and other relevant observations of drill cuttings and how the borehole was constructed. Include boring logs in the UST Regulatory Assessment Report.

1.4.3.3 Precautions. The contractor shall consult with the Camp Stanley POC and the tank operator to properly position the boreholes with respect to site locations, and to avoid underground utilities. A utilities map, if available, shall be consulted before any boring activities take place.

1.4.3.4 Air Monitoring During Drilling. The contractor shall monitor the ambient air during all soil boring work with a photoionization meter or equivalent organic vapor detector to identify the generation of potentially hazardous and/or toxic vapors or gases. If soil encountered during borehole drilling is suspected to be hazardous because of abnormal discoloration, odor or air monitoring levels, containerize the soil cuttings in drums and prepare a manifest for base documentation. Enter into the boring logs the depth(s) for which suspected contaminated soil cuttings were collected.

1.4.3.5 Sealing Boreholes. The contractor shall tremie grout the boreholes to the surface with a bentonite/cement slurry. Boreholes must be adequately resealed to preclude future migration of contaminants (if present).

1.4.3.6 Marking Borehole Locations. The contractor shall permanently mark each soil boring location. Record the location on a project map for each specific site or zone, whichever is applicable. Include borehole map in the UST Regulatory Assessment Report.

1.4.3.7 Material Disposal. Contaminated borehole cuttings will be drummed and left on-site for disposal by Camp Stanley personnel. Clean cuttings will be used at the discretion of the Camp Stanley POC. Camp Stanley will assist the contractor by providing equipment to handle the clean drill cuttings.

1.4.4. Inspections and Records

The contractor shall designate a Field Team Leader (FTL) to remain on the job site during site activities. FTL oversight is especially important during sampling and analysis efforts. The Field Team Leader shall ensure that all phases of the field work are in compliance with appropriate regulations, job specifications, and safety requirements to insure that all phases of on-site work is documented according to industry standards and job specifications.

1.5 Reports and Plans

The following reports and plans shall be prepared by the contractor:

1.5.1 UST Regulatory Assessment Report. The contractor shall prepare and submit a detailed report documenting the status of the Camp Stanley UST system. This report shall contain the regulatory requirements and compliance dates for the tank system. This assessment shall include relative cost estimates for the requirement options. A report shall also include documentation of field activities, locations of the tanks and ancillary piping and equipment, locations of underground utilities which are potential contaminate receptors, laboratory analyses of soil samples, sample chain-of-custody forms, and the surrounding land uses. All field notes taken by contractor personnel shall be available for inspection.

1.5.2 Health and Safety Plan

A Health and Safety plan shall be developed in accordance with 29 CFR 1910.120. This plan shall define emergency procedures, discuss any hazards that could be encountered during site preparation, address accident prevention, and present appropriate action levels for any contaminant likely to be encountered.

1.6 Miscellaneous Requirements

A contractor representative shall attend a kick-off meeting within 14 days of receipt of contract award. The kick-off meeting will be held at Camp Stanley, TX.

Two contractor representatives shall attend a review meeting prior to beginning work on the draft UST report to discuss the findings and the report format.

2. SITE LOCATION

Camp Stanley
Boerne, Texas

III. POST SUPPORT

Camp Stanley shall support contractor activities by providing the following:

-- An escort to assist in site visit.

-- Access to the sites during daylight hours, Monday through Friday while work is in progress.

-- Emergency response points of contact.

-- Locations of underground utilities at the site (preferably marked on the ground surface).

-- Disposal of any hazardous waste generated during borehole drilling activities.

-- Equipment for the handling of clean drill cuttings.

4. GOVERNMENT-FURNISHED PROPERTY

The government shall provide contractor with blueprints and/or plans for USTs and nearby underground utilities (if available).

5. GOVERNMENT POINTS OF CONTACT

AL Project Officer
Lt Nancy S. Miller
AL/OEBE
Brooks AFB, Texas 78235
(512) 536-3305
FAX 512-536-3945

Mr. Fred Stahl
Camp Stanley Storage Activity
RRAD
24800 Ralph Fair Road
Boerne, TX 78006
(512) 221-7441
FAX 221-7463

6. DELIVERABLES

Documents. In addition to sequence numbers 1 and 5 listed to attachment 1 to the basic contract, which apply to all orders, the sequence numbers and dates below are applicable to this order:

Seq.	para	Block 10	Block 11	Block 12	Block 13	Block 14
4 H&S PLAN	1.5.3	OTIME	7DAC	8DAC	N/A	2
4 Reg Ass. Rpt	1.5.4	ONE/R	90DAC	91DAC	120DAC	2

TABLE 1.   LABORATORY ANALYSES

Parameter	US EPA Method	# OF SAMPLES
BTEX	8020	60
TPH	418.1	60

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Excitatory amino acid antagonists attenuate light induced c-fos gene expression in the hamster SCN

Becky Buckley

Sustained Operations Branch
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Brooks AFB, TX . 78235-5301

Introduction

Mammalian circadian rhythmicity has been studied in great detail in order to determine the underlying mechanisms which generate and entrain behavioral rhythms to environmental day/night cycles. The light-entrainable pacemaker is located in the ventral hypothalamus, in association with the suprachiasmatic nuclei (SCN; 16). When environmental cues are absent, the pacemaker continues to measure time and oscillates with its own natural period. The pacemaker, therefore, must be an endogenous clock which measures time by a physiological mechanism. However, in the presence of an 24 hour light-dark (LD) cycle, the period of the pacemaker oscillation is adjusted to reflect that of the LD cycle.

Disruption of circadian rhythmicity is brought about by surgical isolation or bilateral lesions of the SCN (17), and restoration of rhythmicity is accomplished by fetal SCN transplants (7,8,11,19). In addition, in isolated preparations of the SCN, a pronounced circadian rhythm in 2-deoxyglucose utilization persists, which parallels the activity changes observed in the intact animal (13). This

evidence suggests that the biological mechanism generating circadian rhythms is found within the SCN.

The SCN receives a direct, retinal projection via the retinohypothalamic tract (RHT, 14) and an indirect retinal projection via the geniculohypothalamic tract (GHT, 2,13,15). The GHT projects from relay neurons in the intergeniculate leaflet and may convey photic information to the neurons in the SCN (13,15). After geniculate lesions in the rat, both light-activated and light-suppressed cells in the SCN still responded and could be recorded (9). However, surgical disruption of the RHT completely blocks photic entrainment of the SCN pacemaker (16). This indicates that the RHT alone can mediate light activation and suppression, and therefore, can support photic entrainment of circadian rhythms in mammals.

Photic entrainment of the SCN circadian pacemaker occurs as a consequence of phase-dependent alterations in pacemaker function as defined by the phase response curve to light pulses administered to animals maintained under constrant darkness (21). At early subjective night, light pulses caused phase delays of the pacemaker, while at late subjective night, light pulses caused phase advances. Light pulses administered during the mid-subjective day caused neither phase advances nor phase delays. (21).

Photic effects on the SCN pacemaker are mediated through the release of neurotransmitters from RHT terminals. The best candidates for the RHT neurotransmitters are 'he excitatory amino acids (EAA), glutamate and/or aspartate. Stimulation of the optic nerve in the hypothalamic slices increases

release of ^{3}H-glutamate and ^{3}H-aspartate in the SCN (12). Excitatory amino acids work through both the N-methyl-D-aspartate (NMDA) and the non-NMDA receptors. Both types of EAA receptors have been found to exist on the same cell and work in concert with one another (3). The non-NMDA receptors are responsible for the fast EPSP resulting in membrane depolarization necessary for the activation of the NMDA receptors. The NMDA receptor gates a calcium channel and medates a somewhat longer postsynaptic activation of the cell. The infux of calcium through the NMDA-gated ion channel may be the first step in a cascade of reactions leading to stimulus-transcription coupling in the brain (5,6). Recent work in the laboratory of Dr Rea, and elsewhere (4), suggest that the light-induced release of excitatory amino acids causes permanent phase shifts of the circadian pacemaker and that this effect is mediated through NMDA receptors.

Since light-induced phase shifts and the shifts were permanent, it was thought that gene transcription was being activated. Rea (14) and others (1,9) found that light pulses capable of causing phase shifts of the SCN pacemaker induced the expression of the transcription control gene, *c-fos*. Furthermore, Kornhauser et al., (9) reported that light-induced *c-fos* expression and light-induced phase shifts showed similar intensity and phase dependencies. These findings suggest that there is a correlation between light-induced phase shifts and *c-fos* gene expression in the SCN.

Lutton and Rea (unpublished data) demonstrated that excitatory amino acid antagonists, MK-801 ((+)-5-methyl-10, 11-dihydro-5-H-dibenzo [a,b]cyclo-

hepten-5-10-imine maleate) for the NMDA receptor and CNQX (6-cyano-7-nitroquinoxaline- 2,3-dione) for the non-NMDA receptor, block light-induced phase advances at late subjective night by acting directly on the SCN. Furthermore, Curran and Morgan reported that NMDA may trigger c-fos expression by gating calcium channels, thereby providing the intracellular signal for transcriptional activation (6). In this report, we show that both the non-NMDA receptor antagonist, CNQX, and the NMDA antagonist, MK-801, attenuate light induced c-fos expression in the hamster SCN.

Materials and Methods

Stereotaxic Surgery

Male, Syrian hamsters (Charles River) were housed 6 per cage under LD 14:10 (lights on at 1900 and off at 0900) for at least 2 weeks prior to stereotaxic implantation of guide cannulae. Rat chow and water were provided ad lib. The 26- gauge guide cannulae and 33-gauge infusion cannulae were obtained from a Plastic Products and cut to proper lengths. Stylets were manufactured from 33-gauge stainless steel wire and fitted to the guide cannulae. Hamsters weighing between 120-180 grams were anesthetized with 90 mg/kg of sodium pentobarbital (i.p.) and were given 0.1 cc more 10 minutes post-injection. The animals were then placed in the stereotaxic apparatus. The dorsal aspect of the parietal bones was exposed and two screw holes were drilled on each side of the midsaggital suture. The guide cannula-stylet assembly was inserted at a

10° angle into the brain, aimed at the SCN (from bregma; AP:+0.8 mm, L:-1.5 mm, V:-2.8 mm below the dura matter). Dental cement anchored the assembly in place. (fig. 1). The incisions were sutured (Vicryl 4-0), and the animals received 0.05 cc of 0.3 mg/ml buprenex (i.m.) and were placed in separate cages until the anaesthesia wore off. The animals were left in constant light until the next morning at which time they were given 0.5 ml of buprenex (i.m.) and placed back into LD 14:10 at 0900 where they remained for 7 to 10 days.
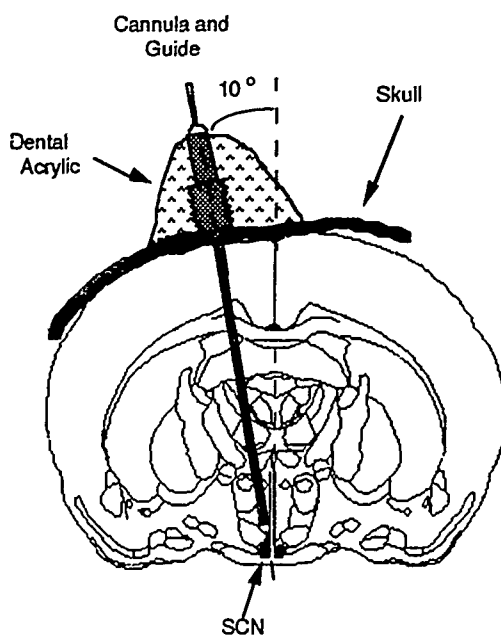
Fig. 1: The guide cannula assembly implanted in the brain
directed at the SCN. The assembly is fixed at a 10° angle to
the midsaggital line.

Photic Stimulation

At 0900 on the day before light stimulation, the hamsters were transferred to DD. After 30 - 32 hours in DD (i.e., mid-subjective night on the following day), the hamsters received 300 nl of either (a) 1 % DMSO in artificial CSF (aCSF), (b) 1 mM CNQX in aCSF, (c) 1 mM MK-801 in aCSF, or (4) no treatment. The injection was administered using a 33 gauge infusion cannula attached to a 1 µl Hamilton syringe. The infusion cannula extended 4.2 mm below the end of the cannula guide , directly above the SCN. Five minutes after injection, each animal received a brief exposure to white light I (10 min at 40 lux). The light stimulation apparatus was a Vivitar Model 2000AF slide projector, consisting of a 150 W tungsten-halogen lamp (type A1/216), a glass infrared filter and a series of collimating and projection lenses. The light intensity was adjusted to 40 lux using neutral density filters. Intensity was verifed using a Tektronics J-16 photometer with the illuminance probe located 1 inch below the top of the stimulation chamber. The conical stimulation chamber (10 cm diameter x 6 cm deep) kept the animal's head oriented toward the light source so that the animal received constant retinal stimulation during the ten minute period.

Immunohistochemistry

Two hours after stimulation, the hamsters were deeply anesthetized with 0.35 cc of sodium pentobarbital and perfused transcardially with 100 ml of heparinized saline and 100 ml of 4% paraformaldehyde in 0.1 M sodium

phosphate buffer (pH 7.4). Brains were removed, cut into blocks and fixed in 4% paraformaldehyde overnight. On the following day, they were transferred to 0.1 M sodium phosphate buffer for 24 hours andcut into 75 µm-thick slices on the Vibratome (WPI). In preliminary experiments, autoradiographic localization of radiolabeled CNQX revealed that a 300 nl injection of the drug occupies a sphere with a diameter of approximately 1.2 mm centered around the site of injection. Therefore, the sections of injected animals were examined microscopically and the ones containing an injection site within 0.5 mm of the SCN were immunostained. The sections were washed twice with phosphate buffer and incubated at room temperature in 0.1 M sodium phosphate buffer containing 2 % Triton X-100, 0.1% bovine serum albumin and 2% normal goat serum (TPBG). Next, the sections were incubated for 30 minutes at 4°C in polyclonal rabbit antiserum (kindly provided by Dr Michael Iadarola, NIDR) diluted 1:5000 in TPBG. The antiserum was raised against synthetic M-peptide, corresponding to residues 127-152 of the *c-fos* protein (Fos), and recognizes a number of Fos-related antigens. After incubation, the sections were rinsed with PBS and processed with the Vectastain ABC kit (Vector labs) using diaminobenzidine as the chromagen. Positive control incubations were performed using brains from hypertonic saline injected rats as described by Sagar et al. (1988), and negative controls were performed by omitting the primary antiserum. The stained slices were mounted, dehydrated, and cover slipped. The number of Fos-immunoreactive cells was determined by microscopic examination. Immunoreactive cells were counted three times and

22-7

the average of the counts was considered for the statistical analysis.

Results

Representative photomicrographs of sections of hamster brains immunostained for Fos are shown in Figure 2. Fos-immunostained cell nuclei appear as brown spots. In all cases, Fos immunoreactivity was confined to cell nuclei. No immunoreactivity was observed in negative control sections which did not receive antiserum.

Cell count data are shown in figure 3. Hamsters which received light stimulation without drug treatment exhibited the greatest amount of Fos expression. The vehicle + light stimulated animal showed a lesser amount of Fos expression on both sides of the SCN (885 ±95: n=11) than in the SCN of the light stimulated (1055±110: n=6). However, this difference was not statistically significant (p<0.14). Therefore, the hamsters injected with the excitatory amino acid antagonists were compared to those injected with vehicle (control).

Light stimulated animals given CNQX (640±109: n=8) compared to vehicle + light stimulated hamsters (885 ±95: n=11) showed a significant (p<0.05) 30% decrease in Fos expression on both sides of the SCN (figure 3). The injection side of the SCN had a slightly greater degree of inhibition (35%, p<0.02). Hamsters which received injections of CNQX without light stimulation showed no Fos expression in the SCN, although slight expression

Vehicle + Light

CNQX + Light

MK-801 + Light

MK-801 Alone

Representative photomicrographs of histological sections of hamster brain immunostained for Fos. Dark brown regions at the tops of the photos represent injection sites.

was seen around the injection site. The CNQX+light stimulated animal had approximately the same amount of Fos expression as seen in the (+) MK-801+light stimulated hamsters.
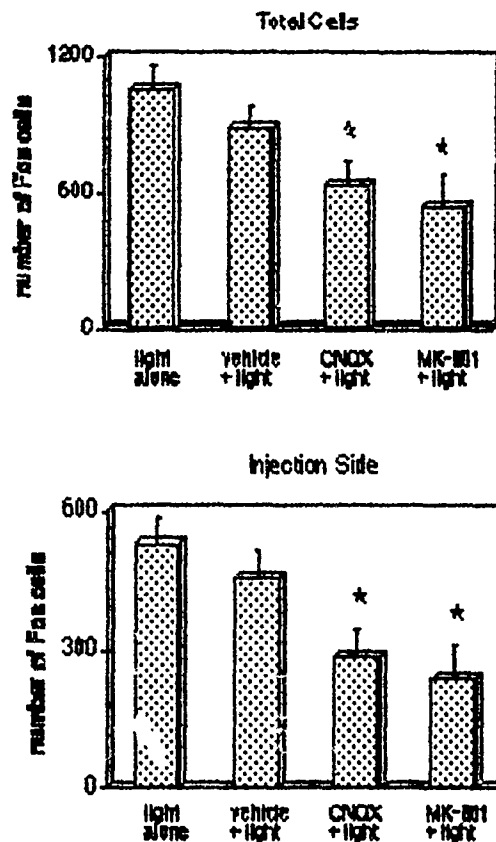
Figure 3. Effect of EAA antagonists on light-induced Fos expression in the hamster SCN. Data represent the mean + SEM of 6 - 11 animals. Asterisks (*) indicate statistically significant differences (p<0.05) relative to the vehicle + light group as determined using he Students 't' test.

Hamsters which received injections of (+) MK-801 + light exposure showed reduced numbers of Fos immunostained cells in the SCN. In comparison of the vehicle + light and (+) MK-801 + light animals revealed a significant reduction in the number of Fos immunoreactive cells in the SCN.

Statistical analysis showed a 40% decrease in the number of immunostained cells on both sides of the SCN (538 ± 143; n=7; p<0.03,). On the injected side of the SCN there is a 47% decrease in the number of fos cells (236 ± 74; n=7; p<0.02) . Also, as observed with CNQX injection, the (+) MK-801 injected hamster that did not receive light exposure showed no fos expression.

Discussion

The results show that excitatory amino acid antagonists, CNQX and (+) MK-801, attenuate light induced Fos expression in the hamster SCN. Furthermore both drugs blocked expression in approximately 40% of the SCN neurons that respond to light. Collingridge and Bliss (3) have shown that both receptors are on the same cells in the hippocampus and may mediated long term potentiation. The NMDA receptor may play a role in the activation of the c-fos protooncogene, which in turn facilitates the long term adaptive response. Our data suggest that a similar mechanism may be responsible for long term alterations in circadian pacemaker function induced by light exposure

It is not clear why the antagonists to the NMDA or non-NMDA receptors do not totally block fos expression but do completely block phase advances. It may be that the cells which are blocked by the excitatory amino acid antagonists are the pacemaker cells and that the other immunostained cells play some type of supportive role. In order to determine if the excitatory amino acids activate fos without photic input, a study can be performed using NMDA and/or AMPA. By

injecting them, we may show that excitatory amino acids cause fos expression independent of photic input.

Since GABA neurons have been shown to modulate the activity of SCN neurons, as well as the response of the SCN pacemaker to light stimulation (23), it may be of interest to study the effects of GABAergic antagonists (23) on Fos expression. There are two different types of receptors for GABA neurons: $GABA_A$, a post-synaptic receptor and $GABA_B$, a presynaptic terminal receptor (20). Therefore, if a $GABA_A$ antagonist such as bicuculine, or a $GABA_B$ antagonist such as phaclofen were injected into the region of the SCN, we might observe effects of these drugs on light-induced Fos expression at different times of the day. Both antagonists should cause disinhibition, resulting in increased release of excitatory amino acids and, therefore, increased Fos expression. Further studies using GABA agonists and antagonists may show that at different times of the day, distinct GABAergic systems are active in the SCN. It is possible that during the subjective day, when light does not induce phase shifts or Fos expression (9), tonic GABA-ergic activity may attenuate retinal input into the SCN.

Within the next decade we may have a drug whcih can be administered orally, cross the blood brain barrier and work specifically on the SCN. The drug may affect the GABAergic regulating system, allowing the SCN to be responsive to photic input at a specific time of the day thereby resetting the pacemaker. This would be very useful for shift workers, individuals with sleep disorders, jet pilots and others living or working in conditions that are incompatable with the

circadian timing system.

Acknowledgements

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Computer Image Analysis of Growth Characteristics of RAW 264.7 Mouse Macrophage Cells

Christopher J. Collumb

ABSTRACT:

The computer can allow for quick unobtrusive analysis of growth patterns and cell densities of cultured cells without the use of microscopy. RAW 264.7 cells are grown in culture at 37° C in 8-well Lab-Tek slides. Various stages of cell growth can be recorded by scanning the culture surface with an HP flatbed scanner attached to a Mac IIci. The cells may be either fixed and stained or still living. Cell density can be recorded as a greyscale value. Greyscale values can be obtained by thresholding the wells of the slide. After thresholding these values can be plotted to show cell growth over time. As the numbers of cells per well varies so to will the greyscale value vary. The fixed cells are stained prior to scanning causing the cells to appear dark to the computer. Thus the more cells present the higher the greyscale value of the well. The living cells are whitish and reflect the light of the scanner. Thus the more cells present, the lower the greyscale value. The greyscale values of both the fixed and living cells can be plotted and graphed to show the growth curve of the cells. The methodology provides a quick approach to monitor cell growth in cell culture.

INTRODUCTION:

Most methods used to obtain information about cells disturb the cells in some manner. In electron microscopy the cells must be fixed, normally in gluteraldehyde, stained in OsO_4, and dehydrated through an alcohol

progression. For transmission electron microscopy (TEM) the cells are imbedded in Spur resin, and in scanning electron microscopy (SEM) the cells are coated in gold or similar conductive metal. In light microscopy very often the cells are stained and fixed. To obtain cellular counts, either by Coulter Counter or hemacytometer, the cells must be removed from where they were growing, and placed in the proper chamber for counting. In addition, in the case of the hemacytometer, the cells must also be stained. Thus for all or these procedures, the cells examined are not in their natural state, and once examined they can not continue to grow.

By using the computer analysis system and procedures described in this paper, one can analyze cell growth *in situ* with virtually no disturbance and without killing the cells.

PROCEDURE:

Cells were grown in a T - 75 falcon flask, cultured up to 6 days. Cells were removed from the flask by scrapping and suspended in 20 mls of PBS. This cell suspension was centrifuged for 5 min to obtain a pellet. The resulting supernatent was poured off. The pellet was resuspended into 5 ml of RPMI. The cell suspension was counted with a Coulter Counter to obtain cellular density. From this stock suspension various dilutions can be made to obtain specific cellular densities. For general purposes, a density of 100,000 cells/ml is prefered. This density is low enough to allow log phase growth but is high enough to be clearly visible to the optical scanner. With this cell suspension Nunc 8 well Lab Tek slides are seeded with 0.5 ml of suspension in each well, except for well number 8 in which 0.5 ml of RPMI is added to create a blank. The blank allows the greyscale "noise" of the slide base and culture media to be removed.

The cells are incubated at 37^0 C. Originally, slides would be removed at various times and fixed in 3% gluteraldehyde in 0.1 M phosphate buffer for one hour to overnight (exact time over the minimum fixation time is not important). The wells were washed in three, five minute 0.1M sodium phosphate buffer washes, stained for one hour in 1% OsO_4 in phosphate buffer and washed in four, distilled water washes. Then the cells were dehydrated in a 25%, 50%, 75%, 95%, 100%, 100% ethanol series. At each step the cells were left in the ethanol for five minutes. The slides were then placed in amyl acetate overnight (long enough to allow the amyl acetate to evaporate).

The processed slides were scanned with a Hewlet Packard Scan Jet Plus flatbed scanner and the digitized image was stored on a Macintosh IIci. To minimize scanning variance, the slide was placed in the same area of the scanner. The average greyscale value for each culture well was obtained by using the thresholding tool from Enhance 1.0.1 software. The greyscale values for the wells at each culture time were averaged and the blank value was subtracted from the average greyscale to obtain the true cellular greyscale value. The numbers obtained at each culture time could be plotted to show cell growth over time.

After creating the procedure and obtaining reliable data for fixed and stained cells, the same type of system of analysis was applied to living cells which were still in culture media. Stock cellular suspensions were obtained in the same manner, and the Lab-Tek slides were seeded and cultured in the same way as well. However, instead of fixing, staining, dehydrating, and then scanning the slide; the slide was scanned directly into the computer upon removal from the incubator. After scanning, the slide was replaced into the incubator to be cultured until the next scanning time. Thus, the

same slide could be examined, at each time period. Greyscales for the wells were obtained the same way as for the fixed wells. The greyscale values for each culture time were averaged and blank subtracted and plotted to obtain the growth curve.

RESULTS:

Figure #1 is an image of a fixed and stained slide captured off of the flat bed scanner. It shows the well positions and the greyscale increase of the slide where cells are present. Wells #1 thru #7 are cells that were seeded at 200,000 cells/ml and cultured for 18 hours. Well #8 is the blank, it represents the greyscale value of the slide base. By subtracting the blank from the greyscale value of the wells, the greyscale value of the cells alone is obtained.

Figure #2 is an image of live cells in culture media captured off of the flat bed scanner. Wells 1 thru 7 contain cells seeded at 200,000 cells/ml and cultured for 24 hours. Well #8 is the blank, it represents the greyscale value of the slide base, media solution, and well covers.

Figure #3 is an image of fixed and stained cells captured on the flatbed scanner at various culture times. Each slide was seeded at 200,000 cells/ml. A slide was fixed, stained and captured at 1 hr, 18 hr, and 96 hr of culture time. The Image shows that, as the culture time increases, the greyscale value of the well increases.

Graphs #1 thru #4 are representations of greyscale data from fixed and stained cells. Graph #1 shows the increase in greyscale as the culture time increases at a seed rate of 100,000 cells/ml. Graph #2 shows that the increase is linear. Graph #3 shows the greyscale increase over a longer

Seed rate
200,000
1 hour
incubation

Seed rate
200,000
18 hour
incubation

Seed rate
200,000
96 hour
incubation
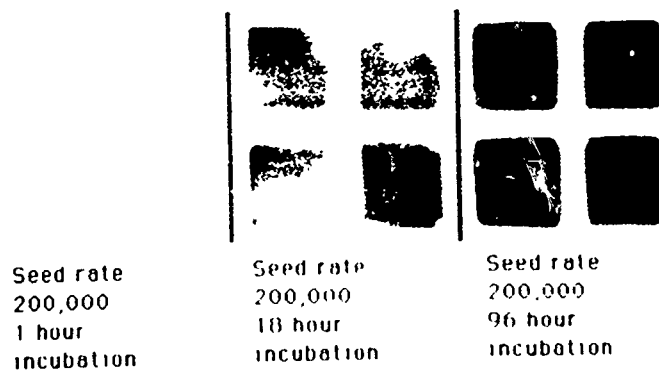
Photo 3. Flatbed image of fixed and stained wells at
various culture times. Note how the wells become
darker as culture time increases.

Fixed and Stained cells
Averaged and Blank Subtracted
Seed Rate: 100,000 cell/ml
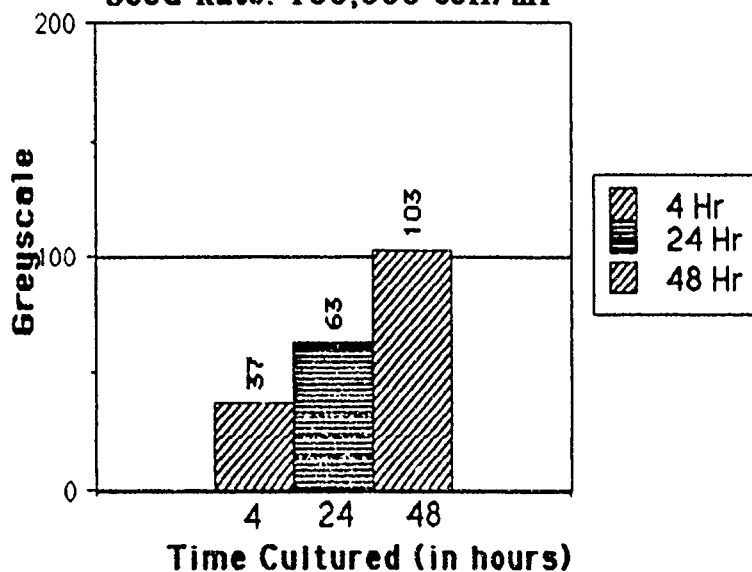
Graph 1. Greyscale values of the wells increase as culture time increases. At each time
step a slide is removed from incubation, fixed stained, and dehydrated The greyscale
values are obtained with the threshold tool in Enhance 1.0.1.

culture time and at a seed rate of 200,000 cells/ml. Graph #4 shows that the increase at longer culture times is logarithmic.

Graphs #5 thru #8 are representations of greyscale data from live cells in culture. Graphs #5 thru #7 show the decrease in greyscale as the culture time increases. Each of the graphs show a different slide seeded at 100,000 cells/ml. Graph #8 shows that all of the slides showed linear growth at the lower seed rates and shorter culture time.
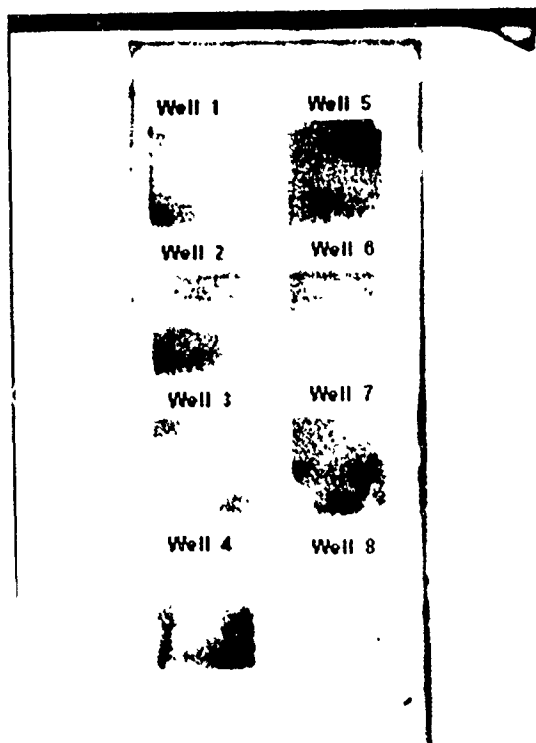
Photo 1: Image of slide after fixation, staining and dehydration. Well 8 is the blank.
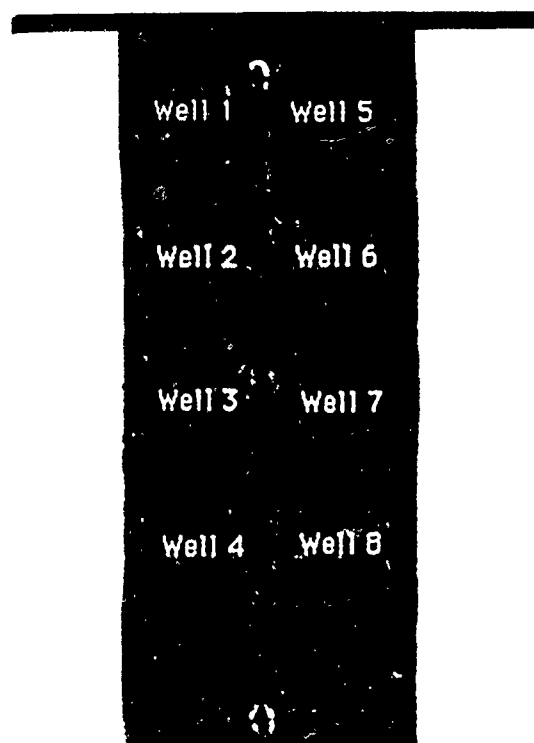
Photo 2: Flatbed image of the slide while cells are still alive and in culture. Well 8 is the blank.

Fixed and Stained Cells
Averaged and Blank Subtracted
Seed Rate : 100,000 cells/ml

$$y = 29.527 + 1.5055x \quad R^2 = 0.995$$
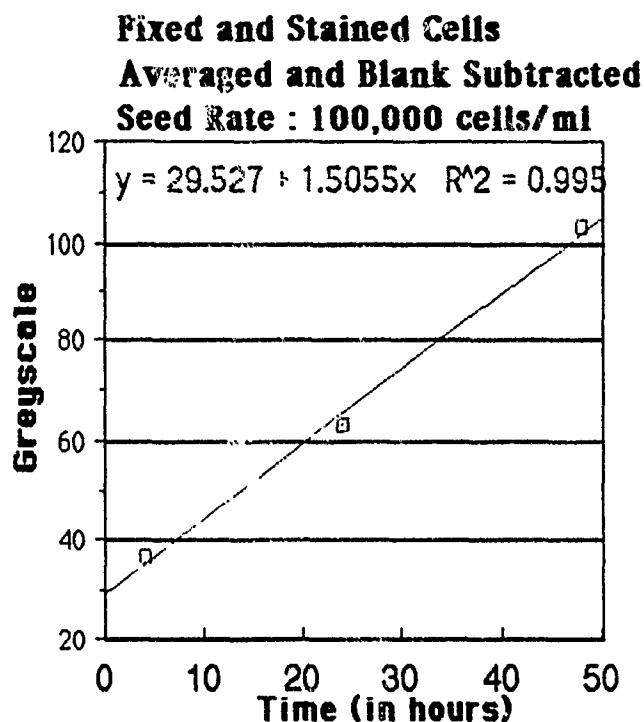
Graph 2: The values from Graph 1 replotted in a scatter plot. The cells show linear growth at low seed rate and short culture times.

Fixed and Stained Cells
Averaged and Blank Subtracted
Seed Rate: 100,000 cells/ml
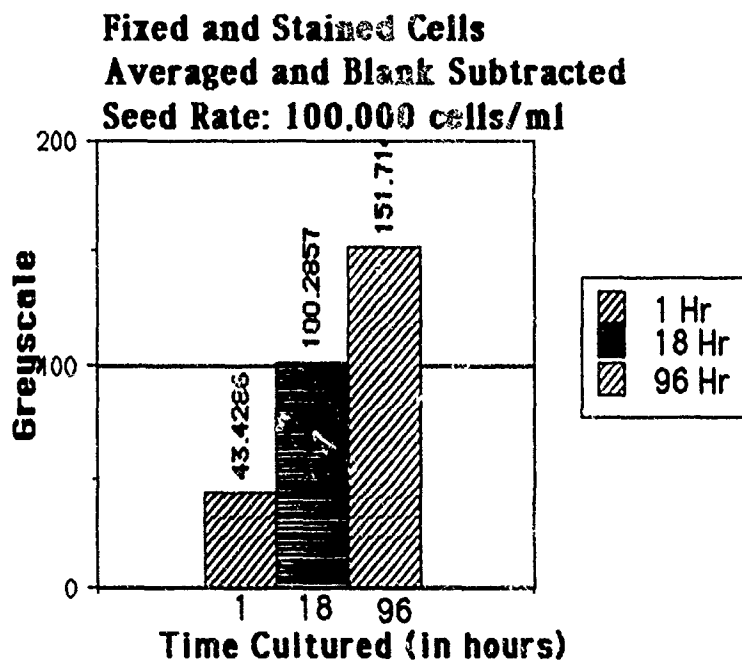
Graph 3: Greyscale values of wells increase as culture time increases.

Fixed and Stained Cell Data
Averaged and Blank Subtracted
Seed Rate: 200,000 cells/ml

$y = 40.633 + 53.595*LOG(x)$ $R^2 = 0.985$

□ Column 1
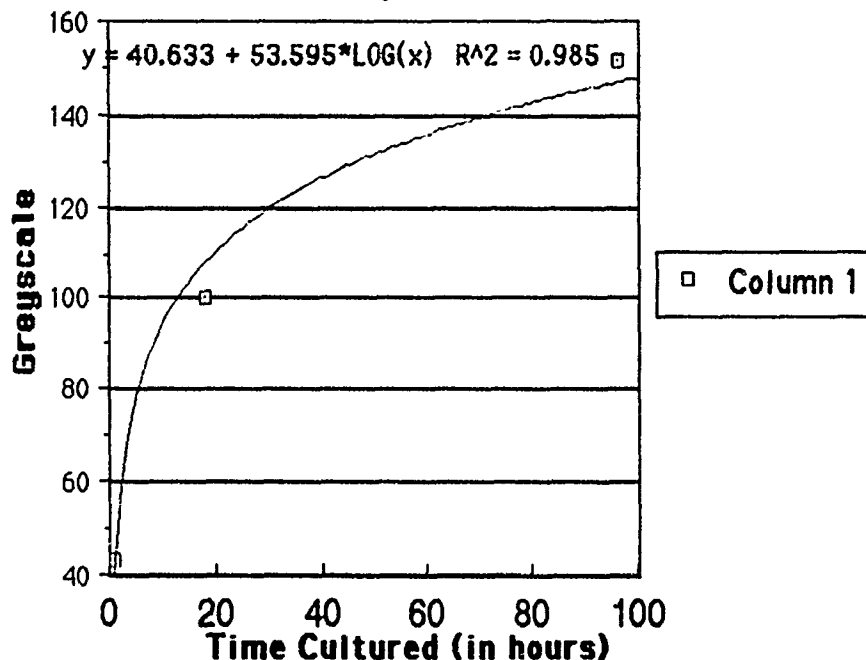
Graph 4: Cell growth becomes logarithmic as seed rate is increased and culture time increases.

Live Cell Data
Averaged and Blank Subtracted
100,000 cells/ml

19.29   17.57   15.71   11.29

6-20 100
6-20a 100
6-20b 100
6-20c 100

Time Cultured (in hours)
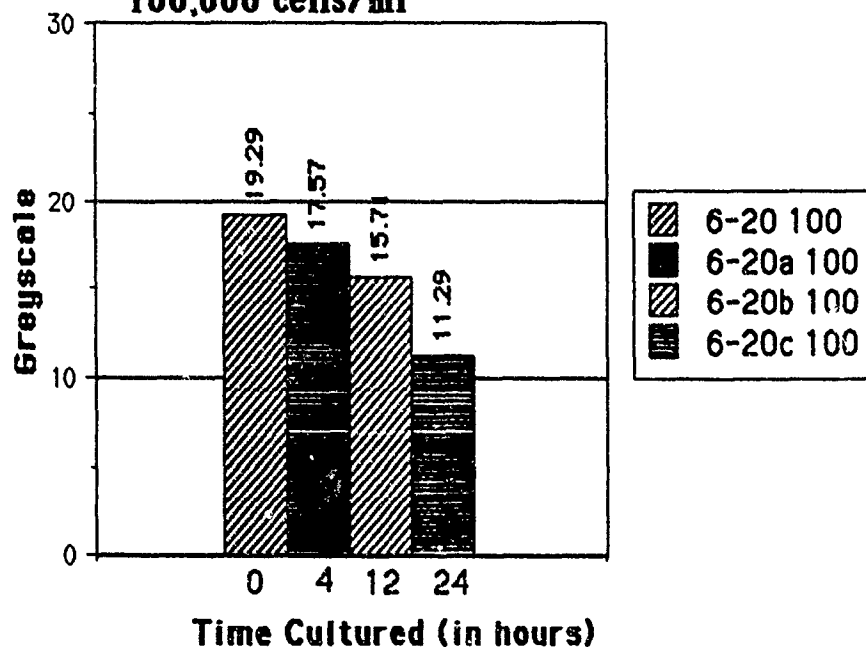
Graph 5: Live cell: The greyscale decreases as culture time increases. The same slide is looked at, at each culture time.

Live Cell Data
Averaged and Blank Subtracted
Seed Rate: 100,000 cells/ml
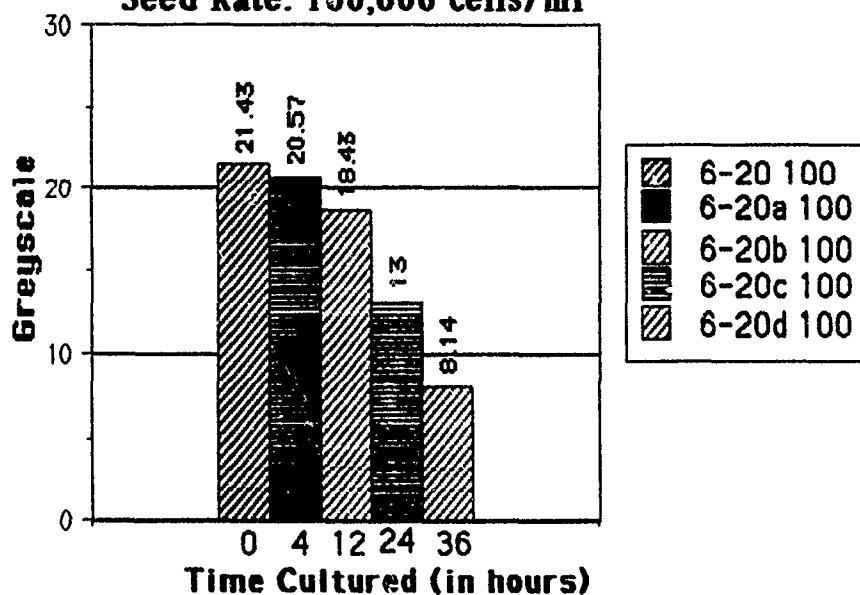
Graph 6: Live cells; greyscale decreases as culture time increases

Live Cell Data
Averaged and Blank Subtracted
Seed Rate: 100,000 cell/ml
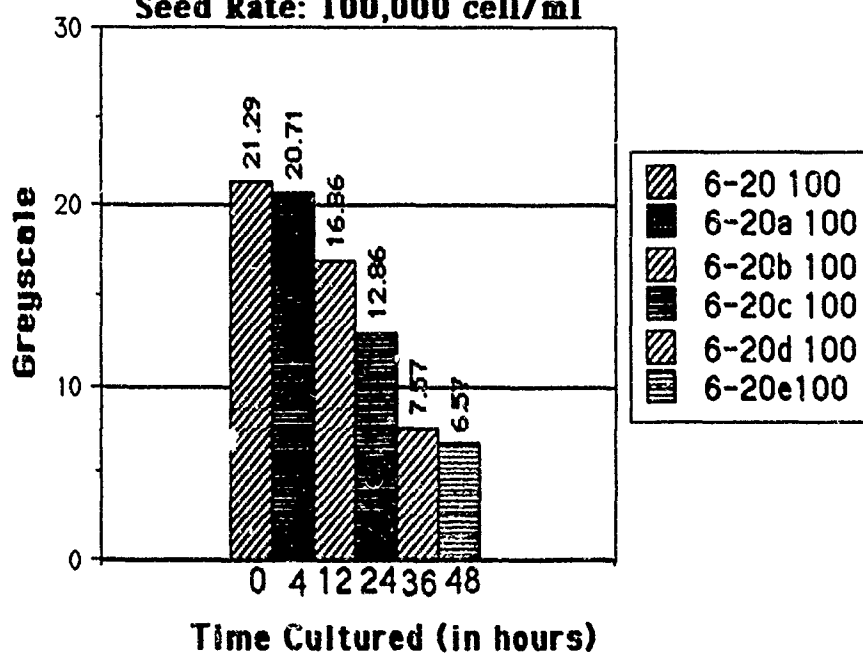
Graph 7: Live cells; greyscale decreases as culture time increases

Live Cells Data
Averaged and Blank Subtracted
Seed Rate: 100,000 cells/ml

y = 2.4300 - 2.5860x   R^2 = 0.941

y = 6.5590 - 3.4150x   R^2 = 0.921

y = 7.0120 - 3.7720x   R^2 = 0.967
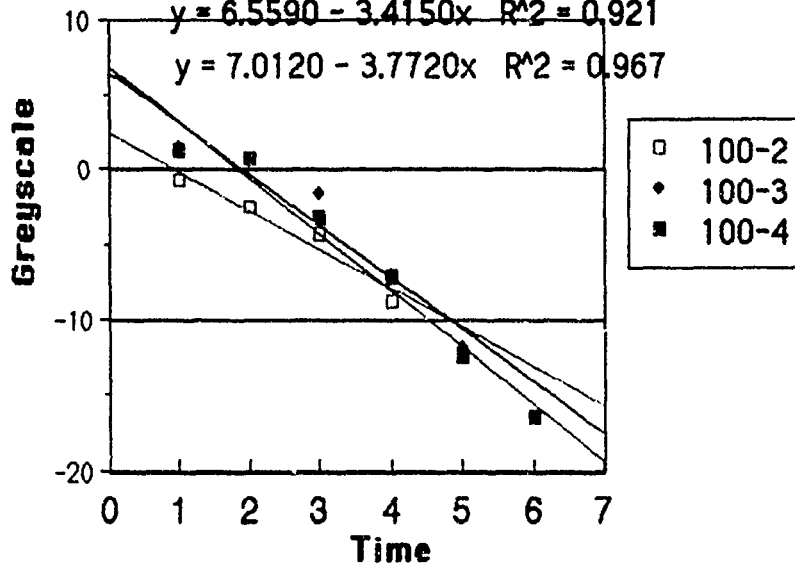
Graph 8: Live cells: The cells show linear growth similar to the fixed cells over short periods of time at lower seed rates.

CONCLUSION:

The data shows that the greyscale values of the cells in the well indicate a clear stepwise increase in greyscale over time in the case of the fixed cells, and a decrease over time for the living cells. The fixed and stained cells appear black to the computer so the more cells present, the darker the well will be. Thus, as culture time increases, and as a result the number of cells increases, the greyscale will increase. By plotting the greyscale increase on a scatter plot and using a best line fit the growth pattern of the cells is clearly shown. At lower seed rates and shorter culture times the pattern is linear, while at higher seed rates and culture times the growth is logarithmic. By contrast the living cells which are whitish will lower the greyscale value of the well as culture time increases and cellular

numbers increase. The scatter plot once again show a tight fit to linear growth at the lower seeding and culture time.

The continuing research goal is to be able to give cell numbers, not just growth trends, from greyscale values. By using known seed values and by scanning the slide before cellular division can take place, assignment of cellular counts to specific greyscales may be possible. This will allow precise cellular counts without the type of disturbance present when using a hemacytometer or Coulter Counter.

BARORECEPTOR CONTROL OF BLOOD PRESSURE FOLLOWING SIMULATED MICROGRAVITY IN HIGH AND LOW FIT SUBJECTS

CRAIG CRANDALL M.S.

Abstract

Following microgravity exposure, astronauts have been reported to have decreased blood volume, maximal aerobic capacity, and orthostatic tolerance. Prior research demonstrate the loss of blood volume alone is insufficient to explain the observed decreased tolerance to gravitational ، .ess. It has been hypothesized that microgravity induced detraining may reduce baroreflex responses to a given drop in blood pressure. The purpose of this report is to present a proposal to evaluate the response of the carotid sinus, aortic, and cardiopulmonary baroreflexes following detraining. In addition, the responses of these baroreflexes to perturbations in arterial and central venous blood pressures in high and low fit individuals will be investigated to determine if microgravity induced detraining elicits a greater change in blood pressure regulation in one group versus the other. The proposed investigation makes use of novel procedures to isolate the three distinct baroreflexes. The carotid sinus baroreceptor reflex will be examined by placing a lead collar around the anterior two-thirds of the subjects neck. Suction and pressure will be applied such that carotid sinus distending pressure will be altered. To determine the effectiveness of this baroreceptor, the changes in R-R interval, as well as vascular responses at various carotid sinus pressures, will be measured. Sub-hypotensive lower body negative pressure (LBNP) will be employed to examine the cardiopulmonary baroreflex. Graded LBNP will be applied from -5 to -15 mmHg. At each stage, heart rate, forearm vascular resistance (FVR), central venous pressure (CVP), and mean arterial pressure (MAP) will be recorded. The slope of the relationship of the decreases in CVP to the changes in FVR represents the responsiveness of this baroreflex. The aortic baroreflex will be evaluated by infusing phenylephrine HCl to increase MAP 15 to 20 mmHg,

resulting in a increased wall tension of all three baroreceptors. LBNP induced decreases in CVP will be used to bring the cardiopulmonary baroreceptor wall tension back to control tensions. Sustained neck pressure will stabilize the carotid sinus baroreceptor wall tension to control levels; at which time the aortic baroreceptor mediated reflex is isolated. Heart rate, FVR, and MAP will be measured at each stage. Sodium nitroprusside induced reductions in MAP (-15 to -20 mmHg) along with lower body positive pressure and neck suction will be employed to observe the responses of the aortic baroreceptors during a hypotensive condition. During the isolation procedure of the aortic baroreflex, the interaction occurring between the three distinct baroreflexes will also be observed. In addition to assessing the discrete and interactive responses of the three baroreflexes, orthostatic tolerance and blood volume measurements will also be obtained pre- and post-detraining. From these results, it is anticipated that we will be able to assess the baroreflex alterations due to detraining. Moreover, we will be able to conclude whether detraining is more disadvantageous for aerobically trained individuals.

Introduction

Prolonged inactivity invoked by microgravity exposure or bedrest causes cardiovascular deconditioning with accompanying orthostatic intolerance. The mechanism by which orthostatic intolerance becomes manifest has been suggested by Blomqvist and Stone (1983) to be a result of an inadequate filling volume and/or depressed baroreflex mediated responses to a fall in arterial pressure. Microgravity induced cardiovascular deconditioning results in a decreased blood volume and therefore a decreased filling volume at any given gravitational stress. Recent studies have shown that alterations in the carotid-cardiac baroreflex do exist following both simulated microgravity (Convertino et al., 1990) and actual space flight (Nicogossian et al., 1991). We have documented an interaction between cardiopulmonary baroreceptors and carotid sinus baroreceptors that are distinctly

different in high and low aerobically fit populations (Pawelczyk and Raven, 1989). Moreover, it appears that isolated aortic baroreflex responsiveness is also different in individuals with differing levels of aerobic fitness (Shi et al., 1991). Indeed high fit individuals have been found to be less tolerant to orthostatic stress, and this was the basis of the argument to restrict extremely high fit individuals from the astronaut corps (Klein et al., 1977; Stegemenn et al., 1974). Of greater importance to the space program should be the investigation as to whether these individuals are more susceptible to orthostatic intolerance following space flight, and if they are, by what mechanism. In reviewing the effect of detraining, three models have typically been used: (1) active detraining, (2) head-down rest (HDR), and (3) space flight.

ACTIVE DETRAINING

Coyle et al. (1986) demonstrated that after 2-4 week of active detraining (cessation of all forms of aerobic activity) trained individuals exhibited a decrease in blood volume (BV) of 9% that was paralleled by a 12% decrease in plasma volume (PV). The results indicated that stroke volume decreased 12%; maximal oxygen uptake (VO2max), as measured with upright cycling, decreased 6%; while heart rate (HR) and total peripheral resistance (TPR) increased during submaximal exercise. Interestingly, when blood volume was expanded to pre-detrained levels, all the previously mentioned parameters were not significantly different from pre-detrained levels. Therefore, it was concluded that the decline in cardiovascular function from detraining was a result of a reduction in blood volume. Unfortunately, orthostatic tolerance tests were not conducted before or after this procedure. It would have been interesting to see if the reinfusion of plasma volume was sufficient to improve post-detraining orthostatic tolerance.

Fritsch et al. (1989) observed the carotid-cardiac baroreflex before and after two weeks of detraining which was preceded by ten weeks of regularly scheduled exercise. Most astronauts have a very difficult schedule two weeks prior to launch such that they are

not able to continue any aerobic training. These researchers wanted to determine if this two week period of no aerobic exercise was detrimental to the astronauts' ability of the carotid sinus baroreceptors regulation of blood pressure. They found the chronotropic response to changes in carotid sinus distending pressure was attenuated, suggesting a decreased sensitivity of the reflex following two weeks of active detraining.

PASSIVE DETRAINING - HDR

HDR is an effective physiological simulation of microgravity (Kakuria et al. 1976; and Blomqvist and Stone, 1983); therefore, it has been extensively used as a model of microgravity induced detraining. The physiological adaptations of HDR are very similar to active detraining, however the changes are much more rapid. Nixon et al. (1979) observed these changes during 24 hours and demonstrated that HDR produced a central fluid shift, orthostatic intolerance, and reduced exercise capacity. The decreased orthostatic tolerance and reduced exercise capacity were suggested to be a result of diuresis and reduced blood volume. However in a similar 24 hour HDR study, Blomqvist et al. (1980) reinfused saline sufficient to bring CVP back to pre-tilt values (approximately two time the volume loss during the HDR) into half of the subjects, and compared these subjects' orthostatic tolerance to that of the other half. The reinfusion of saline was not sufficient to change the orthostatic tolerance, concluding that blood volume alone was not responsible for the decrease in tolerance.

To determine if the baroreceptors may play a role in post-space flight orthostatic intolerance, Convertino et al. (1990) studied the vagally mediated carotid-cardiac baroreflex following 30 days HDR. It was concluded that passive detraining reduced the subjects' ability to respond to changes in blood pressure detected at the carotid sinus, and this reduced baroreflex would contribute to the orthostatic intolerance observed following HDR. Furthermore, they observed the shift in the carotid-cardiac baroreflex was not

correlated with the observed decrease in plasma volume; thus suggesting the reductions in plasma volume and carotid sinus baroreflex sensitivity were independent of each other.

Using a non-human primate model, Billman et al. (1981) put whole body casts on rhesus monkeys and placed them in the horizontal position for 28 days. At control and days 7, 14, and 28 of passive detraining, they observed the changes in the R-R interval due to a 30 mmHg increase in arterial pressure brought upon by a bolus injection of phenylephrine. The monkeys had a markedly reduced chronotropic response to the rise in blood pressure as early as 7 days of horizontal body casting, which persisted for the duration of the study. This further suggests that passive detraining could decrease the baroreflex responsiveness to changes in blood pressure.

PASSIVE DETRAINING - SPACEFLIGHT

It is well know that detraining caused by microgravity exposure results in a decreased blood volume, decreased maximal aerobic capacity , and decreased orthostatic tolerance (Blomqvist and Stone, 1983). What is not well known is the response of the baroreflexes to microgravity. Only two studies have measured baroreflex function following space flight; one recently completed following SLS1, however the results are not yet available. The other study was conducted on a series of shuttle missions of 4-5 day duration (Fritsch et al., 1990). Data was collected on the carotid-cardiac baroreflex using a collar around the subjects' neck to alter carotid sinus transmural pressure, while observing changes in the R-R interval both prior to launch and after landing. The results obtained following the flight indicated the baseline R-R interval was reduced (1135±52 vs 964±30 msec). Additionally, the slope of the estimated carotid sinus pressure to R-R interval tended to decrease after landing, however not significantly due to large prelaunch variation (5.37±1.22 vs 3.2±0.47). It was concluded that the carotid-cardiac baroreflex function may be impaired due to as little as 4-5 days microgravity exposure.

AEROBIC FITNESS AND DETRAINING

Using four hours of HDR, we have demonstrated that endurance trained subjects (VO_{2max} = 62 ml/kg/min) exhibit a larger reduction in blood volume, VO_{2max}, and orthostatic tolerance following the procedure when compared to untrained subjects (VO_{2max} =38 ml/kg/min) (Williamson et al. 1991). Furthermore, LBNP experiments conducted on board Skylab reported that two individuals with higher maximal aerobic capacities exhibited decreased tolerance to this stress during as well as post-flight (Johnson et al., 1977). Unfortunately due to the small sample size, the statistical significance of this study's results are difficult to determine. Goldwater et al. (1980 and 1981) showed that individuals with higher aerobic capacities had greater reductions in LBNP tolerance as well as +Gz acceleration tolerance following HDR. These data suggest that detraining results in a decreased ability of the highly aerobic trained individuals to regulate their blood pressure control mechanisms during orthostatic stress when compared to untrained individuals. Whether this lack of control could be attributed to changes in the sensitivity of the baroreceptors would be the focus of this study.

Unfortunately, little else has been reported pertaining to the effects of fitness on the magnitude or direction of change of the baroreceptors' sensitivity due to detraining. Furthermore the research has been focused on the effect of detraining on the carotid-cardiac baroreflex, ignoring the cardiopulmonary and aortic baroreflexes. It is vital to understand how detraining alters blood pressure control so that countermeasures may be employed to reduce orthostatic intolerance following space flight. Furthermore, the hypothesis that highly trained individuals experience a greater change in baroreceptor sensitivity following detraining needs to be investigated. It is imperative that more information be obtained in this area to fully understand the mechanisms of microgravity induced baroreflex alterations. For this reason, a study should be conducted which would observe the effects of detraining

on each of the baroreceptor populations of both trained and untrained individuals. The null hypothesis to be tested in this project would be:

- There is no relationship between simulated microgravity induced detraining and changes in the sensitivity of each of the baroreceptor populations.

- There is no fitness interaction with baroreceptor alterations following detraining.

Methods and Subjects

Test Days: Three test days will be required for pre-detraining data collection, while one test day will be required post-detraining. Pre-detraining: Day one will consist of a pre-screening orientation which includes a health history questionnaire, physical examination, resting 12 lead electrocardiogram, maximal graded exercise test (GXT), and 2D echocardiogram. Subjects with positive results on any test will be excluded from the study. Day two will consist of familiarization with the experimental procedures namely, lower body negative pressure (LBNP), lower body positive pressure (LBPP), and neck suction/pressure procedures. Day three will consist of blood volume determination, control testing of the baroreflexes, and an LBNP tolerance test. Post-detraining: This data collection period will consist of baroreflex testing, blood volume determination, LBNP tolerance test, and an additional maximal GXT. Blood volume measurements and baroreflex testing will be conducted on specified days throughout the detraining period.

Subjects: Subjects will be male volunteers recruited from the geographical location in which the study is conducted. A total of twenty individuals (ages 30-50 years) will be recruited. Subjects will be placed into two groups depending on their fitness level: ten low fit (VO_{2max} <45ml/kg/min), and ten high fit (VO_{2max} >60 ml/kg/min). Any potential subject that does not meet the qualification of being either low fit or high fit as we have defined, will be excluded from the study. All testing will conform with the Institutional Review Board For Use of Human Subjects at the location of the testing.

GRADED EXERCISE TEST (GXT) AND VO2MAX DETERMINATION

Subjects will walk at a comfortable pace (3.5 mph) at grades of 5, 7.5, and 10% for two minutes per stage. After this warm-up period, the grade will decrease to 0% and the speed will increase to 5.0-7.0 mph for 4 minutes. Subsequently, the speed and grade will increase by 0.15 mph and 1.5% grade every minute until volitional fatigue. Measurements of oxygen uptake will be made using a dedicated breath-by-breath metabolic analysis system and blood pressure by brachial auscultation. The ECG will be continuously monitored during the GXT. The appearance of the subject and the criteria of Taylor, Buskirk and Henschel (1955) will be used to determine qualitatively and quantitatively if the subject provided a maximum effort. A determination of VO2max will be accepted if a plateau of oxygen uptake is achieved and/or when changes in VO2 of less than 100 ml/min for one minute are demonstrated.

BAROREFLEX CONTROL OF HEART RATE AND BLOOD PRESSURE

Carotid Sinus Baroreflex Function: A rapid neck pressure/suction technique described by Eckberg and Eckberg (1982) and Sprenkle et al. (1986) will be used to quantify S-A node and blood pressure responsiveness to changes in carotid sinus transmural pressure. Briefly, a pressure pulse simulating the normal carotid dP/dt will be delivered to a flexible lead chamber that encompasses the anterior 2/3 of the subject's neck. The pulse will be timed relative to the QRS complex to occur 50 msec after the QRS with a duration of 600 msec. This combination of duration and timing elicits maximum baroreflex slopes (Eckberg, 1976; Eckberg, 1979). A ramp of changing carotid sinus transmural pressure will be delivered from +40 to -65 mmHg by 15 mmHg increments to characterize the full baroreflex response. Pulses will be delivered while the subject holds his breath at functional residual capacity. Solenoid valves connected to a variable vacuum and pressure source will be used to regulate pulse timing, duration, and intensity. The slope of the least-squares regression line fit to the linear portion of the R-R interval to transmural neck

pressure/suction curve represents the responsiveness of the cardiac-carotid baroreflex. At least 5 ramps with correlations more than 0.80 will be accepted. The magnitude of the blood pressure response to neck pressure/suction will be used to calculate the gain of the blood pressure baroreflex. Logistic modeling (Kent et al., 1972) will be used to describe a complete carotid-vascular and carotid-cardiac reflex.

Cardiopulmonary Baroreflex Function: Central venous pressure will be decreased using sub-hypotensive LBNP of -5 to -15 mmHg to selectively unload the cardiopulmonary baroreceptors. After two minutes at a given stage, measurements of HR, BP, CVP, and forearm blood flow (FBF) will be obtained; from FBF and MAP, forearm vascular resistance (FVR) will be calculated. The evaluation of the cardiopulmonary baroreceptors will be accomplished by comparing the relationship between FVR and CVP during the unloading of the baroreceptors (Mack et al., 1987; Pawelczyk and Raven, 1989).

Aortic Baroreflex Function: (Hypertensive Protocol) Graded infusions of phenylephrine HCl (PE) by way of a venous catheter inserted in the antecubital vein will increase MAP approximately 15 to 20 mmHg. The infusion rate required to achieve this change in MAP will be approximately 40μg/minute. After two minutes post-infusion, determinations of BP, HR, FBF, and CVP will be made. At four minutes cumulative time LBNP will be applied at levels sufficient to return CVP to control (pre-PE) levels. After two more minutes (six minutes cumulative) measurements of hemodynamic variables will be made to determine the effect of eliminating an increased pressure stimulus to the cardiopulmonary baroreceptors because of a PE induced increase in CVP. After eight-minutes cumulative time, neck pressure will be applied at 1.4x (Ludbrook et al., 1977) the increase in arterial pressure to reduce carotid baroreceptor transmural pressure to control values. After another two minutes (10 minutes cumulative time) hemodynamic measurements will again be made to determine the effect of exclusive aortic baroreceptor

stimulation on HR and vasomotion. Neck pressures will be continuously adjusted to maintain carotid transmural pressure at control values.

Hypotensive Protocol: This protocol is identical to the hypertensive protocol, except the primary stimulus is hypotension rather than hypertension. Hypotension will be established initially using an infusion of sodium nitroprusside at a rate of approximately $3\mu g/kg/min$ to reduce MAP 15 to 20 mmHg. Lower body positive pressure (LBPP) will be used to return CVP to control levels, while neck suction at a level of 1.2x the decrease in MAP will be used to return carotid sinus transmural pressure to control levels (Ludbrook et al., 1977). These protocols are illustrated in Table #1.

TABLE 1

ANTICIPATED EFFECT ON BARORECEPTOR POPULATION

	Baroreceptor Population		
	Cardiopulmonary	Aortic	Carotid
1. a. Infuse Phenylephrine	⇑	⇑	⇑
b. a + LBNP	⇔	⇑	⇑
c. b + Neck Pressure	⇔	⇑	⇔
2. a. Infuse Nitroprusside	⇓	⇓	⇓
b. a + LBPP	⇔	⇓	⇓
c. b + Neck Suction	⇔	⇓	⇔

DETRAINING PROTOCOL

The individuals will stay in a -6° head down position as described by Nixon et al. (1979) for a period of 16 days such that their VO_{2max} will decrease 20% and reduce blood volume 9%.

LBNP TOLERANCE

Before, and after detraining, the subjects will undergo a ramp LBNP tolerance test. The subjects will lie in the LBNP box with an airtight seal around their iliac crest. The

pressure in the box will decrease progressively through the following stages: control, -5, -15, -25, -35, -45 mmHg for 5 minutes per stage; from then on, the pressure will decrease at a rate of -5 mmHg/2 minutes until pre-syncopal symptoms occur or -100 mmHg. A cumulative pressure-time index will be utilized as an index of orthostatic tolerance.

Techniques of Measurement

Heart Rate: Heart rate will be measured from an electrocardiogram, while beat-to-beat determinations of R-R interval will be made using a minicomputer system accurate to ± 1 msec during neck/suction trials. R-R interval will be recorded on an FM tape and a hard disk drive.

Arterial Blood Pressure: Blood pressure will be determined either directly from the radial artery or a Finapress blood pressure monitor. The Finapress obtains blood pressure by a small occlusion pressure cuff that contains a photoelectronic cell; this is placed around the subject's finger. The subject will experience intermittent filling of the cuff as the machine determines the arterial pressure wave form. If the direct line is used, the consulting physician will use a 1% lidocaine solution subcutaneously before insertion of the catheter to reduce subject discomfort. A pressurized saline/heparin drip infusion (2U/ml) will be maintained during the test. Blood pressure will be detected by way of a disposable transducer and will be collected on FM tape, chart paper, and hard disk drive.

Venous Catheter: The venous catheter will be used for the administration of drugs and possibly to detect peripheral venous pressure (see central venous pressure). This catheter will be inserted into the antecubital vein by the consulting physician. This line will be kept patent by frequent flushes with heparinized saline (10U/ml).

Forearm Vascular Resistance: Forearm vascular resistance will be estimated by dividing arterial pressure by forearm blood flow. Occlusion plethysmographic techniques

will be used to measure forearm blood flow. Volume changes will be measured using a mercury-in-silastic strain gauge. Data will be collected on chart paper.

Central Venous Pressure: Central venous pressure will either be estimated using the "dependent arm" technique (Gauer and Sieker, 1956), or measured directly by way of a central catheter place near the right atrium. The dependent arm technique uses a venous cannula placed in the antecubital vein that is connected to a pressure transducer. The subject is placed in the lateral decubitus position on the same side the catheter was placed. The catheter will be zeroed to the mid-sternal line. In this position, the peripheral venous pressure is a result of a gradient between the central venous pressure and the hydrostatic pressure of the dependent arm. Therefore, changes in central venous pressure will be reflected in the dependent arm. The direct measurement of CVP entails catheterizing the basilica vein with a radio-opaque catheter by the consulting physician. The catheter is advanced into the superior vena cava with the assistance of fluoroscopic observation. CVP will be recorded with a pressure transducer positioned at the suprasternal notch. A slow drip of heparinized saline (10U/ml) will be used to keep the line patent. CVP will be collected on FM tape, chart paper, and hard disk drive.

Blood Volume: Blood volume will be determined using the Evans blue dye dilution technique. Following 30 minutes of supine rest, 3 - 5 ml of Evans Blue will be injected into the antecubital vein. At 10, 20 and 30 minutes post-injection, samples will be collected and spectrophotomeric absorbancy of the plasma will be determined. From the absorbancy, the blood volume will be calculated as described by Nielsen and Nielsen (1962). Acute volume shifts will be determined as a percentage change in plasma volume, based on the changes in hemoglobin and hematocrit as outlined by Greenleaf et al. (1979).

STATISTICAL ANALYSIS

Differences between groups and pre/post detraining to baroreceptor stimulation and LBNP tolerance will be determined using ANOVA and ANCOVA procedures for

repeated measurements. Appropriate post hoc analysis will be used to discern differences when a significant F-ratio has been determined. The probability of rejecting the null hypothesis is set at 0.05.

Expected Results and Conclusion

For many years research has been conducted which lends one to believe that individuals with higher aerobic capacities will exhibit the greatest decrease in orthostatic tolerance. Smaller amounts of data from microgravity induced detraining studies suggest that high fit individuals may be more susceptible to orthostatic intolerance following this procedure. Interestingly, when individuals increase their fitness level, they develop a predisposition to orthostatic intolerance; however when they detrain using simulated microgravity, rather than becoming more tolerant to orthostatic stress they appear to become less tolerant. This suggests the mechanisms of microgravity induced detraining may not be the inverse of those mechanisms that result from aerobic training. This issue is additionally clouded with the problem of defining fitness. The bulk of the studies observing microgravity induced detraining define highly fit individuals as those who have maximal oxygen consumptions less than 50 ml/kg/min, whereas we believe the mechanisms producing orthostatic intolerance are most prevalent in individuals with maximal oxygen consumptions greater than 60 ml/kg/min. This study by design would clarify these issues by observing the possible mechanisms of orthostatic intolerance (changes in blood volume and baroreceptor sensitivity) in two widely dispersed fitness groups. If there is a negative correlation between aerobic capacity and the reduction in orthostatic tolerance following microgravity, this study should be able to identify it as well as the mechanism resulting in such a correlation

As mentioned earlier, microgravity induced orthostatic intolerance is likely to be a result of inadequate filling volume and/or depressed baroreflex response to a decrease in

blood pressure. Blomqvist et al. (1980) concluded the reduction in blood volume alone following simulated microgravity was insufficient to explain the decrease in orthostatic tolerance. Therefore, the primary goal of this project would be to investigate the alterations in baroreflex function resulting from simulated microgravity. To date only the carotid-cardiac baroreflex has been observed following simulated and actual microgravity. Both studies concluded that microgravity exposure will result in a depression of this reflex. If the high fit individuals exhibit a greater reduction in orthostatic tolerance than the low fit individuals following detraining, a larger decrease in the carotid-cardiac baroreflex of the high fit subjects would be expected if this baroreflex plays a major role in the regulation of orthostatic tolerance.

Studies have shown that high fit individuals have a depressed cardiopulmonary reflex gain (Mack et al, 1987). The response of this baroreflex following simulated or actual microgravity exposure has not been observed; therefore the predicted outcome is difficult to determine. If aerobic training produced a depression of the cardiopulmonary baroreflexes and assuming microgravity induced detraining results in the inverse of training, one would expect a larger increase of this reflex gain in the high fit compared to the low fit individuals following detraining. This larger increase would assist in the protection against orthostatic intolerance. However if the mechanisms resulting from microgravity induced detaining are not simply an inverse of the changes from aerobic training, then the alterations of this baroreflex would be difficult to predict.

Only one study has observed the interaction of the aortic baroreflex's control of heart rate across fitness levels (Shi et al., 1991). The aortic baroreceptor's control of heart rate was assessed by observing the chronotropic response to changes in aortic pressure. It was concluded that the aortic baroreflex control of heart rate was greater in the low fit compared to the high fit subjects. With this in mind, as a high fit individual's aerobic capacity becomes closer to the low fit's aerobic capacity during the detraining protocol,

then theoretically the aortic baroreflex would increase its control of the heart rate to changes in aortic pressure following simulated weightlessness. Or, like the cardiopulmonary baroreflex, microgravity induced detraining may react differently than the inverse of training, resulting in a decreased aortic baroreflex control of heart rate.

SUMMARY

This paper presents a proposed research project which would observe the effects of simulated microgravity on the baroreceptors' control of blood pressure in both high and low fit individuals. By isolating the individual baroreflexes (carotid, aortic, and cardiopulmonary), it is hoped that a mechanism of microgravity induced orthostatic intolerance could be elucidated. Furthermore, the changes in orthostatic tolerance between the two groups will be observed to assess whether high fit individuals are more susceptible to orthostatic stress following simulated microgravity exposure, and determine if alterations in the baroreflexes are responsible for this response.

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Manual Tracking Follows Induced Rotary Motion

But Not Roll Vection

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Running Head: MANUAL TRACKING AND INDUCED ROTARY MOTION

ABSTRACT

We investigated whether induced rotary motion (IRM) or roll vection (RV) is responsible for subjects' performance of a manual tracking task. Subjects are known to bias the orientation of a central display when it is surrounded by a rotating visual stimulus. Four experiments were performed in which we systematically varied conditions to evoke IRM and RV in different directions simultaneously, using first a depth manipulation like that of Heckmann & Howard (1991), then an eccentricity manipulation. Manual bias was found in the first two experiments to follow IRM closely, but RV results were indeterminate. Bias and IRM were found to be dominated by the farther of two inducing fields. The purpose of the third experiment was to generalize our finding that induced motion is dominated by the farther of two inducers to horizontally moving inducers more like those of Heckmann & Howard (1991) The last experiment successfully evoked IRM and manual bias without RV in one condition and RV without bias or IRM in another condition These findings are relevant for design of displays which superimpose a smaller, central target (like an attitude display on a HUD) over a distant background.

Introduction

Vection and induced (or apparent) motion are perceptual phenomena that can arise in very similar circumstances. Vection (also called induced self-motion) can be induced in individuals by showing them large, uniformly moving visual scenes. Most often, people experiencing vection feel themselves to be in motion (in a direction opposite to the motion of the scene), while the scene they view is perceived to be stationary. Induced motion is the apparent movement of a stationary target when another object (the inducer) moves relative to it. Large, uniformly moving visual scenes like those that induce vection often make smaller, foregrounded objects appear to move relative to the observer, always in a direction opposite to that of the inducer.

In the present experiments we are interested in the rotary case of each of these phenomena. An inducing stimulus that rotates around a central target makes that target appear to spin in the opposite direction. This is called IRM, for induced rotary motion. Also, an inducing stimulus that rotates around an observer's visual axis (around the point which they fixate) generally elicits roll vection, or RV.

We are interested in the relationship between manual tracking and these two phenomena. Pilots of high performance fighters control the attitude of their aircraft using a manual control, getting orientational information from their primary flight displays. HUDs often have a small, centrally located target (the attitude display) superimposed on a more

distant background. It can be shown that when such a display is superimposed on a rotating background, a person's that is using that display for a manual control task will bias the attitude of that display in the direction of rotation. The question we seek to address asks whether they bias the display because of the presence of IRM or because they are experiencing RV

IRM has two phenomenal components that are commonly reported. The first is an apparent motion of the stationary target, and the second is an apparent static tilt of the target. We believe that subjects who have manual control of a central target bias the attitude of that target because they may be correcting for IRM in that target caused by the inducing stimulus. This effect would be similar to other findings involving rotating frames and the rod and frame illusion (Babler & Ebenholtz, 1990).

It is also possible however, that subjects who have been instructed to keep a central display horizontal fail to do so because of RV induced by the rotating frame. RV also has two phenomenal components, illusory self-motion and illusory self-tilt (Dichgans & Brandt, 1978).

Babler & Ebenholtz (1990) offered a hypothetical explanation of the way in which RV might cause such a bias. the result of viewing a rotating field might be to induce illusory self-tilt, consistent with vection, in a direction opposite to the direction of motion of the field. If the observer does in fact feel tilted with respect to gravity, and they are attempting to keep the display horizontal with respect to gravity (as they were

instructed to), they should bias the display in the same direction as the rotation of the field, thinking gravitational vertical to be somewhere in that direction.

Heckmann & Howard (1991) successfully designed an experiment in which they seperated inducing stimuli in depth. They found that vection (in their case, linear vection) was induced, or dominated by, the farther of the two inducers, while induced motion was dominated by the stimulus that was coplanar with the target. It is our hope that a similar depth manipulation will allow us to seperate out the RV and IRM components and to see which of the two components subject's performance of the manual tracking task follows.

In the present experiment, we hope to find these things: First, we hope to establish that rotating stimuli induce a bias in manual tracking in the direction in which the inducer rotates. Also, we hope that the magnitude of that bias will be inversely related to the amount of depth that seperates the central target and the inducing stimulus, an effect that is called the adjecancy principle (Gogel & Tietz, 1972). In Experiment 1, we will do this using inducing stimuli at each of three depth planes in turn. Second. In Experiment 2 we hope replicate the findings of Heckmann & Howard and find IRM and RV going in opposite directions simultaneously when the conditions are right for it. Third, in Experiment 2 we hope to see manual bias going with either vection or induced motion.

Methods

Subjects

Subjects for Experiments 1, 2, and 3 were 12 people associated with the USAF School of Aerospace Medicine. 6 males and 6 females, ranging in age from 16 to 49 years, were asked to participate on the basis of availability and accessability. One male was an experienced psychophysical observer, and three subjects (all males) had previous experience with the manual task. Candidates were screened for far acuity and stereoacuity using a Bausch & Lomb Armed Forces Vision Tester. All subjects had corrected or uncorrected vision of 20/30 or better and 40' arc stereoacuity or better. Candidates were also given an depth matching test where they were asked to estimate equivalent amounts of near and far depth. Because our method relies on people that have approximately equal ability to process both near and far depths, candidates that showed consistently large near or far biases were not asked to participate in the experiment. 8 out of 12 subjects showed a slight far bias, with the mean bias of all 12 subjects slightly in the far direction.

Because our study needed subjects to experience vection normally, we gave subjects a bare-bones screening for this, to determine if they experienced self-motion in a direction opposite to that of a moving visual scene. We rejected one subject because he failed to experience vection normally. Subjects were treated in accordance with Air Force Human Subjects Standards 169-3.

Apparatus and Stimuli

The experiment was conducted in a darkened booth in the USAF School of Aerospace Medicine's Visual Orientation Laboratory, an illustration of which is contained in a previous report (Previc & Mullen, 1991). The laboratory includes: (a) a Silicon Graphics IRIS 3130 workstation, (b) a SONY 1030Q video projector, (c) a subject booth containing a Draper Cine-15 viewing screen on which the image is projected at optical infinity; and (d) a simulated aircraft seat with a Measurement Systems, Inc. model 446 force-stick attached to its right arm. The video projector is adjustable in height, so that the center of the projected image can be adjusted to visually-perceived eye level for each subject when seated. During the experiments, subjects wore a pair of goggles with a red filter in one eye (Kodak Wratten Gelatin Filter No.29) and a green filter in the other eye (Wratten No. 58) We included a neutral density filter (No 96 ND.0.30) in the red side to equate the luminances for each side.

The inducing stimulus was a field of dots projected on the screen positioned in front of the subject. The subject, whose head was fixed for distance by the headrest of the chair they sat in, viewed the screen at a distance of 71.12 cm (28 inches) through the goggles. This allowed him a field of view 54° horizontally by 44° vertically, with 35° of binocular overlap. The field of view allowed by the goggles was rectangular, although no surrounding border could be seen by subjects when they were viewing the stimuli. This is important because a surrounding contour has

been found to reduce reports of vection and induced motion (Babler & Ebenholtz, 1990).

The inducing stimulus consisted of a field of dots positioned in six concentric rings around the central display. The central display consisted of a central spot surrounded by 4 horizontal lines (top, bottom, right, and left). The overall shape of the central display was hexagonal, 10° across. The first ring was 17.6° in diameter, with about 3.8° space between dots in this ring and the edges of central display. The other rings were 27.2°, 36.7°, 46.1°, 55.3°, and 64.3° in diameter. The size of the field of view was such that the outer most ring could only be seen in the corners.

These rings were made concentric so that when they moved in conflict, no dots from any one ring occluded those of any other ring. Additionally, there were 3 dots in the first ring, 7, 7, 11, 15 and 7 in the second through sixth rings respectively. Dots were placed around the ring at random, though roughly even, intervals.

We introduced disparities into the dots to make them appear near or far when viewed through the goggles. We did this using the anaglyph method, with each eye seeing either the red or the green component. Near dots were given 17 mm crossed (near) disparity, which gave them a virtual distance of 55.2 cm, or 15.9 cm closer in depth to the subjects than the coplanar dots and central display. Far dots were given 11 mm uncrossed (far) disparity, which gave them a virtual distance of 87.0 cm, or 15.9 cm farther in depth from the subjects than the coplanar dots and

central display. We asked subjects if they saw the far dots to have equal depth with respect to the central display as the near dots did. Most subjects reported that the near dots were a little closer in depth to the central display than the far dots were, consistent with the overall far bias we found in our subjects as a group. Dots at all three distances were made to be the same apparent size (about .75° visual angle), although the resolution of the color projector only allowed us to approximate this. When asked, subjects reported that the near dots appeared larger than both the coplanar and far dots, which in turn appeared to be about the same size.

General Design and Procedure

Subjects who passed the screening and gave their consent to be a subject received training on the manual task, and learned the rating scales for both PV and IRM. The manual task is similar to Babler & Ebenholtz's (1990) dynamic RFE task, in that subjects are required to control a central display with horizontal lines and a pivot point, and to keep it as close to horizontal as possible for the duration of each trial. Subjects use the force stick to move the central display, which is perturbed throughout the trial. The computer samples the angular deviation from horizontal of the central display at a rate of 15 Hz. For each trial, we derive the mean deviation from horizontal (bias). The program was set up to generate other measures (stability, RMS error, etc) but we were not explicitly interested in these measures for the present experiments.

The task is rather like keeping a long stick balanced on its end. The central display has a balance point, where the central display lines are horizontal, and as the display falls farther from this point. it falls faster, making more forceful corrections necessary. Subjects are asked to keep the display as close to horizontal with respect to gravity as they possibly can throughout each trial. During each trial, the field of surrounding spots moves in a circle around the display at a rate of 25°/second. Subjects had to learn to do the manual task up to a criterion of 3 72-second trials in a row without losing control of the central display once.

Experiment 1

Design and Procedure

Each subject received 8 trials with all six rings of surrounding dots at each of the three depth planes. They received them in blocks of four trials, with direction of the inducing stimulus alternating every trial. Condition order was counterbalanced in an ABCCBA design. All possible condition orders were used twice (hence twelve subjects). Subjects were asked to rate vection at the end of each manual trial on a scale of zero to five, with zero corresponding to no RV, and five corresponding maximum RV. Subjects were shown a standard scene for RV ratings, a scene which was known from a previous experiment to elicit vivid, saturated vection in subjects. Subjects gave their RV rating at the end of each manual trial. After the twenty-four manual trials, they were given twenty-four more trials where they didn't do the manual task. instead giving IRM ratings for

each of the three conditions, in the same order as for the manual trials. Subjects were asked to rate apparent rotary motion of the central display (which was in fact stationary), also on a zero to five scale. They were offered no standard on which to base their ratings.

Experiment 1 Results and Discussion

For the first experiment we scored biases, RV ratings, and IRM ratings as positive if their values were in the same direction as the inducing stimulus Most biases were positive because manual bias usually was in the same direction as the movement of the inducing stimulus. However, most RV and IRM ratings were negative, because these phenomena usually go opposite to the inducing stimulus.

We performed an ANOVA for each dependent measure. There was a significant main effect for manual bias, with $F(2,22) = 7.49$, $p<.005$. One-tailed t-tests showed each condition to be significantly greater than zero, as predicted (see Table 1). Post hoc comparisons using Student-Newman-Keuls t-test show that the coplanar biases and the far biases were both significantly greater than near biases at $p<.05$, while they did not differ significantly from each other.

There was also a significant main effect for IRM, with $F(2.22) = 11.66$, $p<.001$. As predicted, the coplanar condition had mean IRM scores significantly less than zero. IRM scores for the near and the far conditions were also significantly less than zero. Although this outcome is not predicted by the adjacency principle, it is not denied by it either.

What the adjacancy principle really leads us to expect is that there should be significantly more IRM in the coplanar condition than in the other two conditions. Post hoc analysis was done using a Student-Newman-Keuls t-test, which showed that this was partly true. Coplanar IRM scores were significantly greater than near IRM scores at $p < .05$, but they were not significantly greater than far IRM scores. That this pattern of results agrees with the manual bias results so well it is good evidence that the manual task relies on IRM attributes of the central display, and probably reflects an overall nulling of the induced motion.

There was no main effect for the RV scores. None of the condtions elicited RV that was significantly different from zero, and no post hoc analyses were performed.

Insert table 1 about here

Although they were not significantly different from zero, the RV scores were in the right direction (opposite that of manual biases), which keeps open the possibility that the whole-body tilt that usually accompanies RV was in fact the source for manual biases. The second experiment examined that possiblity, by placing two inducers in conflict with eachother, seperated by stereoscopic depth. Heckmann & Howard's data lead us to expect two things. First, we expect to see RV dominated by the farther of the two inducers. Second, we expect to see IRM be dominated by the inducer in the plane of convergence (the coplanar

stimulus). In the far vs. coplanar condition, then, we should find negative RV (opposite to the far stimulus) and positive IRM (opposite to the coplanar but in the same direction as the far stimulus. If manual bias is significantly negative, we will have a basis for concluding that it depends on IRM cues, while if it is significantly positive, we will have a basis for concluding that it depends on a shift in the perceived gravitational vertical due to RV.

Experiment 2 Methods

Design and Procedure

Each subject received eight trials of each of three combinations of conflicting depth planes: far dots vs. coplanar dots, coplanar vs. near, and far vs near. As in experiment one, subjects received each condition four trials at a time, with direction of the inducing stimuli alternating each trial. Condition order was counterbalanced within subjects in an ABCCBA design. All possible condition orders were used twice. To avoid confounding depth and eccentricity we counterbalanced relative depth and direction of the inner ring on each trial. We did this because we might expect the inner ring of stimuli to dominate induced motion of the central display. Because the inner ring can only have dots at one depth plane at a time, we alternated the inner ring's depth on each trial. We also alternated the direction of the in. most dots in an ABBA design, so that each of the two depths occurred in the inner ring four trials out of eight, and each of the depths occurred an equal number of times in each

direction.

As in the first experiment, subjects completed twenty-four manual trials. reporting the direction and magnitude of vection at the end of each manual trial. After this, they saw twenty-four more trials where they did not control the central display, instead watching it and rating direction and magnitude of induced rotary motion of the central display.

Experiment 2 Results and Discussion

For this experiment we scored biases, IRM and RV as positive if they went in the same direction as the farther of the two inducing fields, and negative if they in the opposite direction as the farther of the two inducing fields. In other words, if RV scores were negative (opposite to the direction of the farther stimulus), then we assumed that RV was induced by farther of the two fields. In the same sense, if IRM scores were positive (in the same direction as the farther stimulus), then we assumed that IRM was being induced by the nearer of the two fields. As stated earlier, the condition where this difference should be most apparent is the far vs. coplanar condition.

A seperate ANOVA was performed for each of the dependent measures. There was a significant main effect for manual biases, with $F(2,22) = 9.54$, $p<.001$. Post hoc analyses were done using Student-Newman-Keuls t-tests. These revealed that the near vs. coplanar conflict condition biases were significantly greater than both the far vs. near and the far vs. coplanar condtions. the first at $p<.05$ and the latter at $p<.01$. Also, the far

vs. near biases were significantly greater than the far vs. coplanars, at p<.05. What this reveals is basically that when the inducing stimuli are placed at two different depth planes, manual bias depends on the farther of the two depth planes.

All three conflict conditions had bi~   that were significantly different from zero. Because bias scor~   ~re positive if they went with the farther of the two depth planes, and all conflict biases were significantly positive, this provides a good basis for evaluating which process contributes to manual bias. If, as Heckmann & Howard (1991) claim, the farther of the two stimuli dominate vection, and vection is negative with respect to the direction of the farther of the two, then perhaps manual bias in fact relies on vection, and not induced motion of the central display, as the previous experiment suggests.

If this is the case, then RV scores ought to reflect this. They do not. There was no significant main effect for RV, with $F(2,22) = 1.71$. If we look at the means anyway (Table 2), we can see that they are not even in the right direction. To produce the putative deflection, RV scores would have to be in a negative direction, which they are not.

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insert Table 2 about here

One might ask why we failed to elicit good RV in either of the first two experiments. We feel that there are two likely reasons for this failure. The first has to do witht the size of the inducer. Our inducing stimulus

subtended about 55° of visual angle. Although this should have been sufficient for eliciting vection, vection does grow stronger with increasingly large stimuli. Also, subjects were asked to rate vection essentially while they were doing the manual task. Such a dual task has been demonstrated to reduce felt vection. The fact that our inducer was smaller, coupled with the fact that the vection rating was done in competition with the manual task may have killed us. In the fourth experiment, we will correct for both of these design flaws.

IRM scores show that this is more likely to be the source for manual bias. There was a marginally significant main effect for IRM, with $F(2,22) = 3.41$, $p<.051$. While no condition was shown to be significantly different from any other using a Newman-Keuls t-test, all conditions had IRM scores that were significantly different from zero. Using two-tailed t-tests, we see that far/coplanar conflict IRM was marginally different from zero, with $t(11) = -2.17$, $p<.053$, with the far dots winning out over the coplanar dots (see Table 2) This represents an outcome that not only fails to confirm Heckmann & Howard (1991), but contradicts their data entirely. If only the coplanar dots were contributing to induced motion of the central display, we would expect positive scores here, with the central display going in the same direction as the far dots.

For the other two conflict conditions, we see the coplanar dots winning out over the near dots, and the far dots winning out over the near dots. Looking at the mean IRM scores for each conflict condition, we can see

that the amount which the fars win out over the nears is not additive, as we might expect. The reason for this is unclear. A clear outcome of this part of the experiment is that induced rotary motion of a central display is determined by the farther of the two inducing stimuli, which is not necessarily the coplanar inducing stimulus. When the coplanar is the farther of the two inducing stimuli (as in the coplanar vs. near conflict condition), it will dominate induced motion. But when the coplanar is the nearer of the two inducing stimuli (as in the far vs. coplanar conflict), it does not dominate induced motion of the central display.

Unfortunately, we failed to achieve our quest for a situation where we effectively place vection and induced motion in conflict. Experiement four will continue that quest by using an eccentricity manipulation. First, though we wish to examine an issue of more theoretical interest. Our data show that IRM is dominated by the farther of two inducers, not necessarily by the inducer in the plane of convergence. This outcome is troubling because it flies in the face of Heckmann & Howard.

One issue that is left unclear by the results of experiment 2 is their generality. Heckmann & Howard (1991) showed that induced motion of a central target is dominated by the inducing stimulus in the plane of convergence. One possible reason for this difference is that they were investigating induced *linear* motion (horizontally rightward or leftward), while we were investigating induced *rotary* motion (clockwise or counterclockwise motion). A recent review (Reinhardt-Rutland, 1988)

suggests that there is good reason to believe that induced linear motion and induced rotary motion are processed differently, and so what holds true for one might not be the case for the other. Experiment 3 investigates this possibility, by using horizontally moving inducing stimuli with a central display, and placing two inducing stimuli in conflict with each other at each of two depth planes (far, coplanar, near) at a time. In this respect, Experiment 3 is a partial replication of Heckmann & Howard's (1991) experiment.

Experiment Three Methods

Because our results from the second experiment appear to contradict the findings of Heckmann & Howard, we wished to find out if the difference was due to the fact that they were investigating induced linear motion, while we were investigating induced rotary motion. To do this, we created inducing stimuli that moved horizontally. We created four conditions, one with coplanar dots only, moving in one direction. The other three conditions had dots in two different depth planes moving in opposite directions. The dots moved at a velocity of 10°/second, in rows that were seperated vertically, so that no dot ever occluded any other. Virtual depth was created using the anaglyph method as for the first two experiments, and the disparities and sizes used were the same as for the first two experiments.

Subjects saw four trials of the coplanar condition first, with direction alternating on each trial. They then saw each of the three

conflict conditions in random order, with all possible orders being used twice. There were four trials in each condition, 16 trials in all. Subjects were asked to rate direction and magnitude of motion of the central display only. Subjects were asked to respond as soon as they got a good idea of the direction and magnitude of apparent motion of the central display, using the same 5-point scale as in the previous experiments. As soon as they responded, the experimenter went on to the next trial, although they were limited to 15 seconds per trial.

Experiment 3 Results and Discussion

We scored ratings of induced motion the same as for Experiment 2. If induced motion went opposite to the far inducing field, it was scored as negative. If induced motion was in the same direction as the far stimulus, then we scored it as positive. Because induced motion usually goes opposite to the stimulus which is inducing it, we would expect negative scores if the farther field is dominating induced motion. and positive scores if the nearer field is dominating induced motion. Heckmann & Howard's (1991) data would lead us to expect significantly positive scores in the far/coplanar conflict condition, with the target going in the same direction as the far field of dots.

There was a significant main effect, with $F(3,33) = 6.56, p < .0013$. Post hoc analyses revealed that there was significantly more IRM reported by subjects in the coplanar only condition than in any of the three conflict conditions. which in itself is not surprising, being consistent with the

findings of Heckmann & Howard (1991). What *is* interesting is that a two-tailed t-test revealed that IRM reported in the far vs coplanar conflict condition was not significantly different from zero, with t(11) = -1.47. Mean induced motion was slightly opposite the far stimuli (see Table 3). Heckmann & Howard's own data showed that in this situation we should have seen a significantly positive result, with the central display going opposite to the coplanar stimuli. This was definitely not the case.

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insert Table 3 about here

Overall, we failed to confirm Heckmann & Howard's findings that induced motion is dominated by stimuli in the plane of convergance. We assume, of course, that our subjects' converged in the plane of the central display. We believe that one of the main differences between our method and that of Heckmann & Howard is that they failed to control for occlusion of the farther stimuli. We think this artifact is probably the source for our disagreements. Specifically, it appears that where Heckmann & Howard concluded that there is only coplanar dominance of induced motion, there is in fact both a coplanar and a far influence on induced motion. When placed in conflict (in the linear case), they more or less negate each other. If the farther of the two inducers is being occluded, this might have the effect of lessening the far influence, leaving induced motion to be almost totally dominated by the coplanar inducer. Pilot observations we conducted where occluson of the far dots was

programmed in tended to support that conclusion.

From a theoretical standpoint, the relationship of induced motion to the stimuli that induce it is interesting. But our quest for conclusive evidence for the relationship between manual bias, IRM, and RV is unresolved. In the last experiment, we will not use the relative depth manipulation. Instead, we will use an eccentricity manipulation. Vection has been shown in the past to be dominated by the periphery, while induced motion depends on the whole visual field -center and periphery. We hope to create a situation where there is good IRM but no RV, using a central inducer only, and a situation where there is good RV but no IRM, using a situation where the central inducer and a peripheral inducer counterrotate. Because we failed to get good RV, will do everything we can to elicit good vection --expand the visual angle of the inducing stimulus, and have subjects rate vection trials seperate from those where they do the manual task.

We expect bias to follow IRM. In the case wher there is a central inducer only, we expect significant bias and IRM in opposite directions, consistent with a nulling explanation, but non-significant RV. In the center vs. peripheral conflict condition, we expect to find significant RV consistent witht the peripheral inducer, but non-significant bias and IRM.

Experiment 4 Methods

<u>Subjects</u>

Subjects were 12 people associated with USAF School of Aerospace

Medicine. No subjects that participated in the first three experiments were in experiment 4. Since this experiment did not entail good stereopsis. subjects were only screened for acuity and vection. Subjects were required to have 20/30 acuity or better in each eye, as tested by a B&L Armed Forces Vision Tester. We rejected 4 candidates before finding the twelve we needed, one for failing to experience normal vection. Subjects were treated in accordance with USAF Human Subjects Standards 169-3.

Apparatus and Stimuli

The apparatus was the same as for the first three experiments, except that we placed a fresnel lens in front of subjects, suspended from the ceiling of the subject booth. Stimuli for this experiment were generated by the IRIS computer. Since these stimuli were not intended to involve stereoscopic depth, subjects did not wear the goggles as they did for the first three experiments. On each trial, subjects were shown the central target surrounded by one of four combinations of inducers. The four conditons were: a) a concentric inner ring only, with an inner radius of 12° and an outer radius of 28.7°, b) a concentric peripheral ring only, with an inner radius of 36.3° and an outer radius of 69.1°, c) the central ring plus the peripheral ring rotating in the same direction (full-field), and d) the central ring and the peripheral ring counterrotating (conflict).

Dots in the inducer rings where actually squares of three sizes. Small squares were 1.1° on a side. medium squares were 2.3°. and large squares

were 3.4°. They were all the same color (red), and luminances were an average of 2.0 ft/L. Due to magnification by the lens, the central display was 16.4°. Inducer rings rotated at 25°/sec.

Subjects got an equal number of trials of each of the four conditions (six each), with an equal number of trials in the each direction. On any given trial, direction and condition were randomly determined. Subjects performed either 24 trials of the IRM task or the RV task first, followed by 24 trials of the manual tracking task, followed by 24 more trials of whichever task they hadn't already done. Condition and direction order were different for each task and each subject. Sessions lasted less than an hour.

Experiment 4 Results and Discussion

There was a significant main effect for manual bias, with $F(3,33) = 14.23$, $p<.0001$. Two-tailed t-tests showed that manual bias was significantly different from zero in all conditions except for the conflict condition at $p<.001$ (see table 4). Bias in the conflict condition ws not significantly different from zero, with $t(11) = 1.60$. This shows us that at least for bias, the outcome was clear cut.

There was also a significant main effect for RV. with $F(3.33) = 26.63$, $p<.0001$. All conditions except for the central condition were found to be significantly different from zero at $p<.001$. The central only condition did produce significant vection, but $t(11) = -3.36$, $p<.0064$. Although this was significant. it was not nearly as significant as bias was in this case.

Also. vection in the conflict condition was significant, while manual bias was clearly not. This alone gives us sufficient reason to conclude that Manual bias does not depend on the amount of vection experienced by subjects.

We can go one step further, though, and see that the IRM results follow bias pretty well. There was a significant main effect for IRM, with $F(3,33) = 18.37$, $p<.0001$. All conditons except for the conflict conditon were significantly different from zero at $p<.001$, while IRM for the conflict conditon was significantly different from zero with $t(11) = -2.50$, $p<.0295$.

If you look at the profiles of each measure (see table 4), it is apparent that both IRM and bias show a nice linear increase from the central to peripheral to full-field conditions, and an abrupt drop off in the conflict condition. Pooled correlation analysis shows that the correlation between bias and IRM is $r = -0.94$, $p<.001$. The correlations between bias and RV are also significant ($r = -0.69$, $p<.005$), as was the correlation between RV and IRM ($r = 0.63$). We feel that the high correlation between RV and IRM is probably responsible for the high correlation between RV and bias. Although our eccentricity manipulation was sufficient, a better manipulation should produce a lower correlation between RV and bias.

General Discussion

We successfully created a situation which seperated out RV and IRM (Experiment 4) and that manual tracking was shown to follow the IRM

component. We also believe that we have shown that the coplanar dominance of induced motion that Heckmann & Howard (1991) showed was contaminated by an occlusion artifact. Instead, we propose that induced motion is the result of a mixture of coplanar and far visual field influences, in both the rotary and the linear cases.

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Table 2

Experiment 2: Means and Standard Deviations of Manual Bias, IRM, and RV

With Inducing Stimuli in Two Depth Planes (Conflicting)

Depth of Inducers	Bias	IRM	RV
Far vs. Coplanar	7.06 (3.36)[5]	−1.08 (1.72)[2]	0.51 (1.28)[1]
Coplanar vs. Near	10.69 (5.36)[5]	−1.72 (1.92)[4]	1.00 (2.09)[1]
Far vs. Near	8.87 (3.49)[5]	−1.16 (1.74)[3]	0.52 (2.04)[1]

[1] $p > .06$

[2] $p < .06$

[3] $p < .05$

[4] $p < .01$

[5] $p < .001$

Table 3

Experiment 3: Means and Standard Deviations of Estimated Induced Motion

Evoked by Four Different Horizontal Conditions.

Depth of Inducer(s)	Induced Motion
Coplanar Only	-3.27 (1.00)[3]
Far vs. Coplanar	-0.88 (2.07)[1]
Coplanar vs. Near	-2.40 (1.20)[3]
Far vs. Near	-1.94 (1.87)[2]

[1] p>.05

[2] p<.005

[3] p<.001

Table 4

Experiment 4: Means and Standard Deviations of Manual Bias, IRM, and RV

With Inducing Stimuli at Four Combinations of Eccentricity

Eccentricity of Inducers	Bias	IRM	RV
Central Dots Only (C)	9.86 (6.29)[4]	-2.60 (0.62)[4]	-0.77 (0.80)[3]
Peripheral Dots Only (P)	12.01 (5.63)[4]	-3.32 (0.92)[4]	-3.25 (1.06)[4]
Full-Field Dots (P + C)	14.23 (8.33)[4]	-3.57 (0.89)[4]	-3.24 (1.22)[4]
Central vs Peripheral			
Conflict (P - C)	1.47 (3.19)[1]	-0.77 (1.06)[2]	-1.50 (0.98)[4]

[1] $p > .05$

[2] $p < .0295$

[3] $p < .0054$

[4] $p < .001$

DERIVATION OF A FINITE-DIFFERENCE TIME-DOMAIN (FDTD) ALGORITHM FOR MODELING DISPERSIVE MEDIA

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ABSTRACT

The finite-difference time-domain (FDTD) algorithm is used to model dispersive material. Since current FDTD algorithms cannot model dispersive media, a reformulation of the traditional FDTD algorithm is required. This can be accomplished by including a discrete time-domain convolution [1] or a differential equation approach [2] that can be used to model frequency-dependent constituative parameters. The traditional Yee formulation uses second-order accuracy to approximate Maxwell's equations. Since it was possible that for highly dispersive media higher-order approximations to Maxwell's equations might be required, finite-difference schemes employing fourth-order accuracy and sixth-order accuracy have been developed and investigated.

INTRODUCTION

The traditional finite-difference time-domain (FDTD) algorithm has been used successfully to analyze a wide variety of problems. The main thrust of this research effort was to reformulate the traditional FDTD to model a Lorentz media in the optical-frequency range.

The Lorentz media provides a good approximation to the frequency-dependent permittivity of water, which is the predominant element in muscle tissue. If water can be modeled in the optical-frequency range, a good approximation to the frequency-dependent characteristics of muscle tissue is available. To model the Lorentz media, both the time-domain convolution integral

approach and the differential equation approach (see Fred German's final report) are used.

In the main body of this report, first the problem will be discussed, outlining the methods employed to develop this algorithm. Results obtained from the various modifications of the traditional FDTD algorithm are provided. These modifications include using higher-order finite-difference approximations to model Maxwell's equations, and using the time-domain convolution integral approach to model both a Debye and a Lorentz media. While the time-domain convolution integral equation approach has not been completely successful in modeling a Lorentz media, results seem to indicate that the method is valid and with further research can be successfully implemented.

PROBLEM DISCUSSION

The traditional Yee formulation of the FDTD algorithm provides direct time-domain integration of Maxwell's equations using a second-order finite-difference approximation to the equations. The derivation of this traditional FDTD algorithm is straight forward [3], however the traditional FDTD algorithm cannu model dispersive media. The goal of this research effort is to modify the traditional FDTD algorithm so that a Lorentz media can be modeled in the optical-frequency range. All the modified FDTD algorithms are one-dimensional algorithms.

Several problems were examined. First, it was possible that a second-order approximation to Maxwell's equations was not adequate for modeling highly dispersive media, so higher order-algorithms were developed. Next, a first order (Debye) dispersion was incorporated

into the FDTD by including a discrete time-domain convolution integral approach. Finally the same technique was employed to attempt modeling a second-order (Lorentz) dispersion.

RESULTS

Higher-Order Finite-Difference Schemes

Consider a plane wave traveling in the +x direction. For this case Maxwell's equations reduce to

$$\frac{\partial B_z}{\partial t} = - \frac{\partial E_y}{\partial x} \tag{1}$$

$$\frac{\partial D_y}{\partial t} = - \frac{\partial H_z}{\partial x} \tag{2}$$

Discretizing space and time coordinates such that

$$(i,j,k) = (i\Delta x, j\Delta y, k\Delta z)$$

$$D(t) \cong D(n\Delta t) = D^n$$

Using second-order accuracy, Yee's finite-difference equations become

$$\frac{B_z^{n+.5}(i+.5) - B_z^{n-.5}(i+.5)}{\Delta t} = - \frac{E_y^n(i+1) - E_y^n(i)}{\Delta x} \tag{3}$$

$$\frac{D_y^{n+1}(i) - D_y^n(i)}{\Delta t} = - \frac{H_z^{n+.5}(i+.5) - H_z^{n+.5}(i-.5)}{\Delta x} \tag{4}$$

Notice that equations (3-4) are simply second order central-difference approximations to equations (1-2). This technique can be easily extended to higher-order approximations of Maxwell's equations.

Using fourth-order finite-difference approximations, Yee's finite-difference equations become

$$\frac{23B_z^{n+.5}(i) - 21B_z^{n-.5}(i) - 3B_z^{n-1.5}(i) + B_z^{n-2.5}(i)}{\Delta t} = \tag{5}$$

$$\frac{E_y^n(i+1.5) - 27E_y^n(i+.5) + 27E_y^n(i-.5) - E_y^n(i-1.5)}{\Delta x}$$

$$\frac{23D_y^{n+1}(i+.5) - 21D_y^n(i+.5) - 3D_y^{n-1}(i+.5) + D_y^{n-2}(i+.5)}{\Delta t} = \quad (6)$$

$$\frac{H_z^{n+.5}(i+2) - 27H_z^{n+.5}(i+1) + 27H_z^{n+.5}(i) - H_z^{n+.5}(i-1)}{\Delta x}$$

Notice that central-difference approximations are not used exclusively for the time term of Maxwell's equations, while central-differences are used exclusively for the spatial term of the equations. This nonuniformity is because higher-order central-difference approximations to the time term of equations (1-2) are unstable. So, a central-difference combined with a backward-difference scheme is used to derive a stable finite-difference approximation for the time term.

Using the same technique, the form for a sixth-order finite-difference approximation to Maxwell's equations can be derived. The general form for this expression is easily derived but fairly complicated. First, defining constants

$$a1 = 20 + 75*a5$$

$$a2 = 3 + 10*a5$$

$$a3 = 1 + 10*a5$$

$$a4 = 5*a5$$

$$a5 = 1/80$$

$$a6 = 22 + 79*a5$$

The form for the sixth-order approximation is

$$U^{n+1}(i+.5) = a1U^n(i+.5) + a2U^{n-1}(i+.5) - a3U^{n-2}(i+.5) +$$

$$a4U^{n-3}(i+.5) - a5U^{n-4}(i+.5) + \frac{\Delta t}{a6\Delta x}(H^{n+.5}(i+1) - 27H^{n+.5}(i) +$$

$$\quad (7)$$

$$27H^{n+.5}(i-1) - H^{n+.5}(i-2) + a5(H^{n+.5}(i+2) - 5H^{n+.5}(i+1) +$$

$$10H^{n+.5}(i) - 10H^{n+.5}(i-1) + 5H^{n+.5}(i-2) - H^{n+.5}(i-3)))$$

While equation 7 appears complicated, it is easily derived and implemented.

To determine how much error was involved with each of these algorithms, an attempt was made to develop an equation describing inherent dispersion in the mesh. While error expressions were easily derived using a Taylor's series expansion, these expressions only provided a vague description of the error. Therefore, a simple qualitative approach was used to compare dispersion in the three different finite-difference schemes.

A unit dirac delta distribution was used as the excitation function for the three different algorithms. For all three cases free space was the media, the mesh size was 300 cells, the cell size was 1mm and 300 time iterations were performed. The excitation and output location was at cell number 150.

Ideally, for all three algorithms the responce would be a unit dirac delta distribution at time step 1 and zero for all other time steps. However, due to dispersion in the mesh itself, this was not the case.

For the above problem, Figures 1-3 show the response from the algorithms using second-, fourth- and sixth-order accuracy respectively. Notice the large dispersion in the response shown on Figure 1. Figures 2 and 3 look much more like delta distributions, although mesh dispersion is still apparent. Due to these results, and the results obtained using other excitation functions, it can be determined that the fourth- and sixth-order finite difference schemes are more accurate than the second-order scheme.
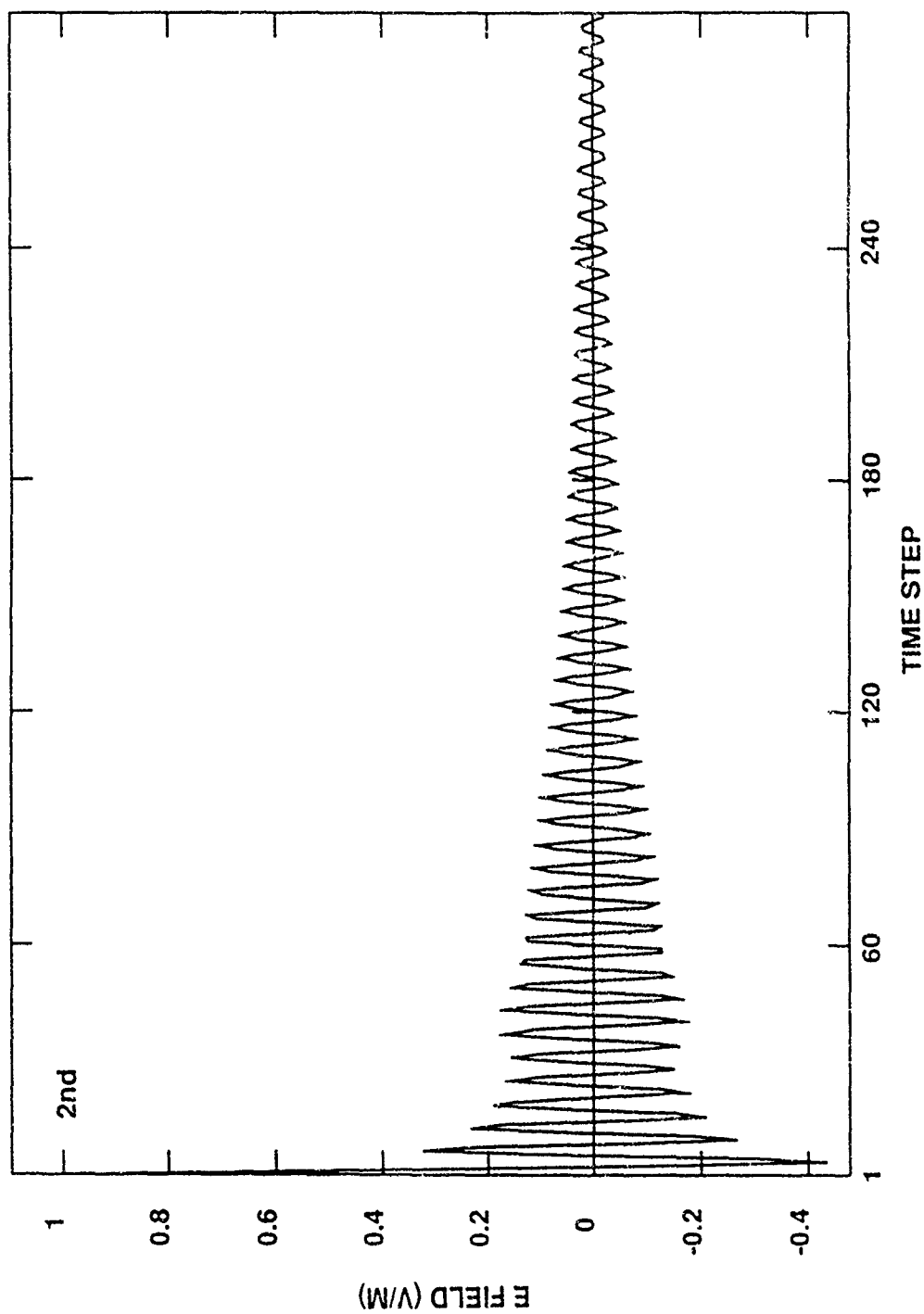
Figure 1. Plot of the Response for a Second Order FDTD to a Unit Delta Distribution.
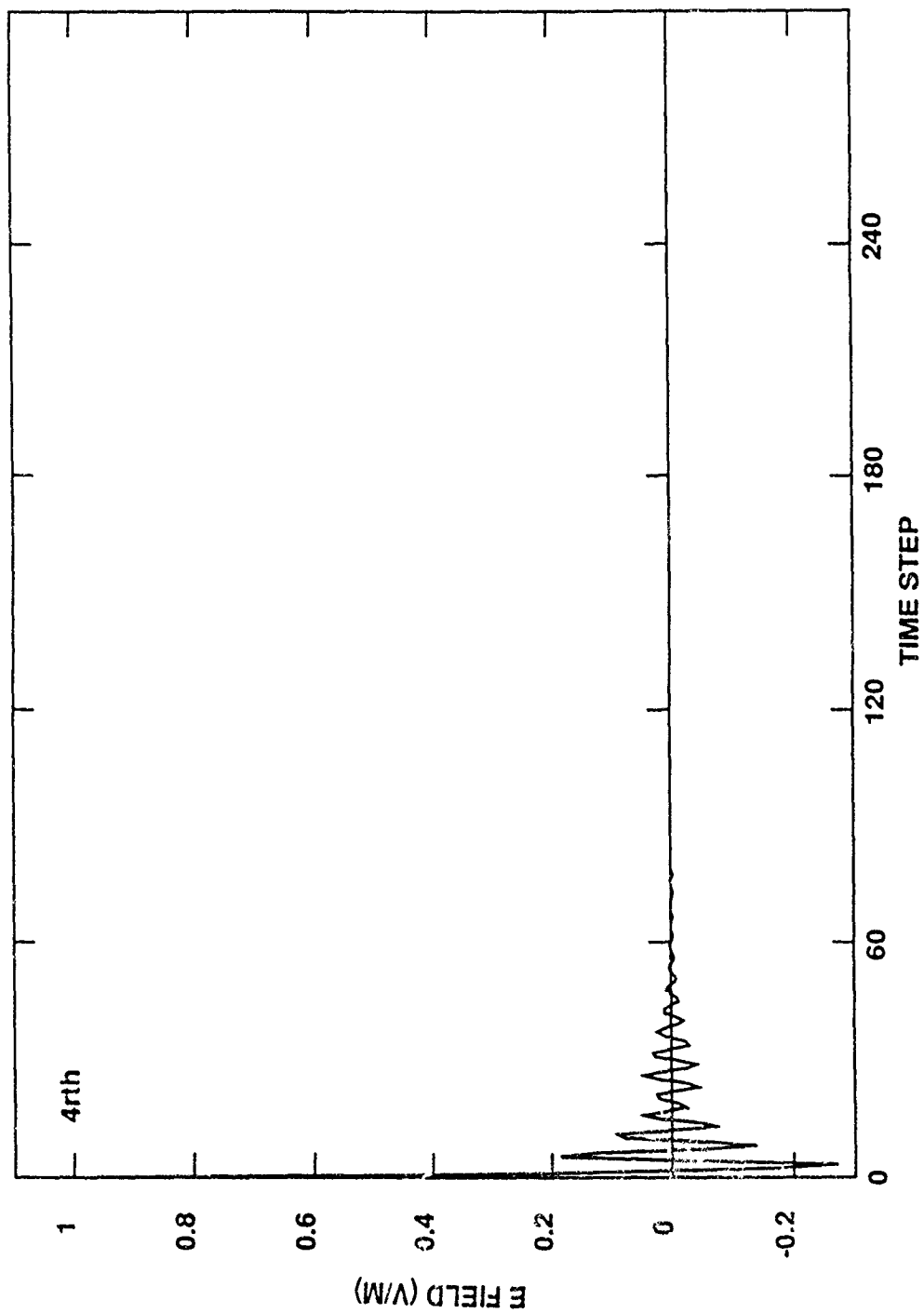
Figure 2. Plot of the Response for a Fourth Order FDTD to a Unit Delta Distribution.
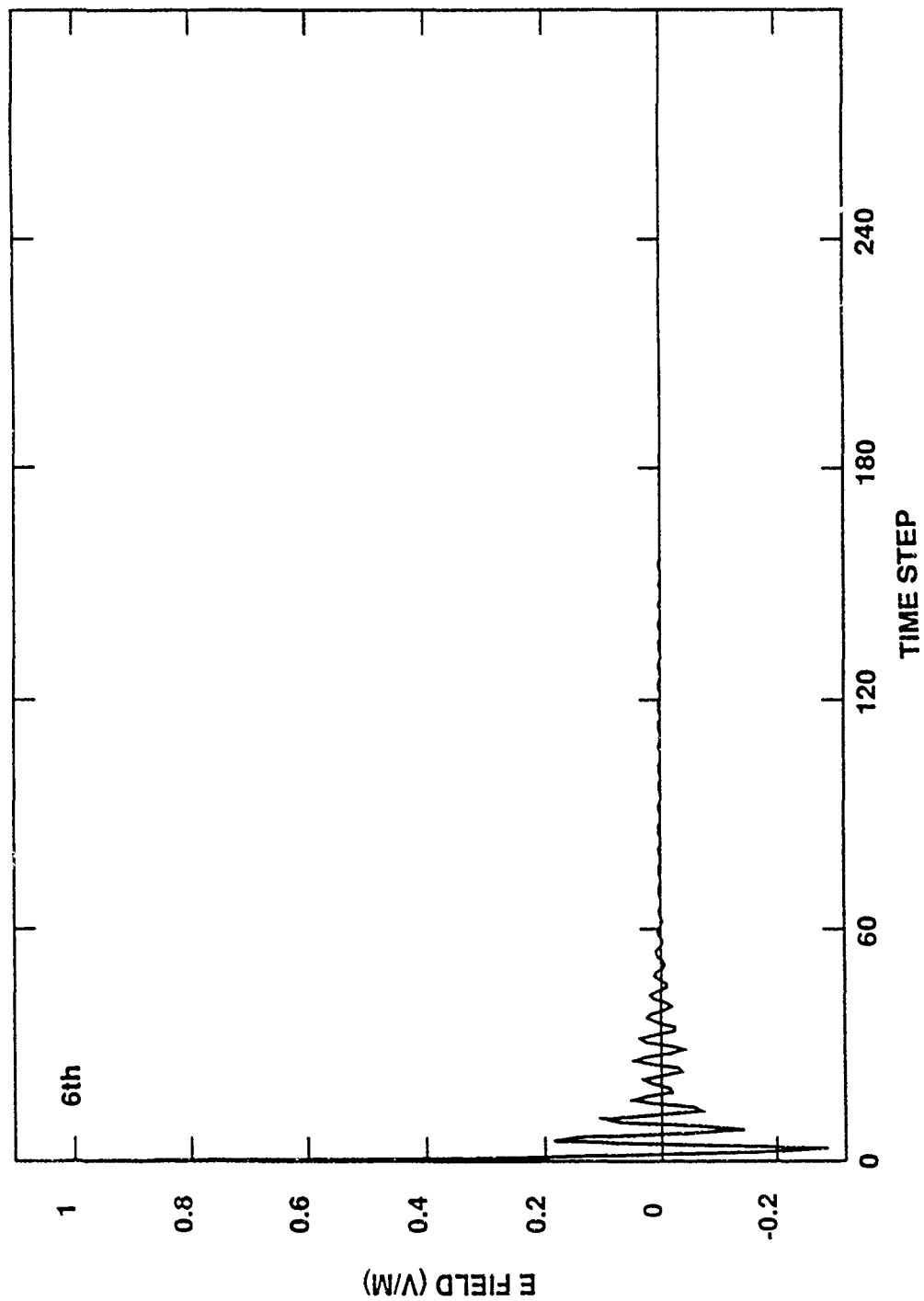
Figure 3. Plot of the Response for a Sixth Order FDTD to a Unit Delta Distribution.

The comparison of Figures 2 and 3 is interesting. It appears that the fourth-order algorithm may be slightly more accurate that the sixth-order scheme. Although the difference is slight, the dispersion shown on Figure 2 'damps out' faster than in Figure 3. This is not to be expected, and may be due to accumulated computer error. The sixth-order algorithm performs significantly more operations at each time step than the fourth-order scheme.

The fourth-order finite-difference algorithm is more accurate than the second-order algorithm. It appears to be at least as accurate, if not more so, than the sixth-order algorithm. Also, my colleague Fred German is concentration exclusively on the second-order FDTD scheme. Therefore, for the increased accuracy obtained and to prevent redundancy, I have exclusively used the fourth-order algorithm for the rest of this effort.

Debye Media

The derivation for an FDTD (second-order) algorithm for a dispersive Debye media is contained in reference 1. This derivation is valid for a fourth-order finite difference scheme. Simply substitute equations (5-6) for (3-4) and follow the same procedures outlined in the reference. This scheme uses a discrete time-domain convolution integral calculated using recursive techniques. This algorithm, modified for order accuracy, was implemented.

A variety of tests were conducted to determine the validity of the resulting dispersive FDTD algorithm.

First, in a half space, the transmission coefficient was determined analytically and compared to the theoretical values over a wide frequency range. The FDTD was used to obtain the incident and

transmitted fields at the boundary of the half space. A Gaussian pulse was used as the excitation function. Taking the Fourier transform of these fields, the analytic transmission coefficient was determined. Knowing the expression for the complex frequency-domain permittivity, the frequency-dependent characteristic impedance of the dispersive media was determined, and then the exact values of the transmission coefficient were calculated at discrete frequencies.

Figures (4-5) show the comparisons. Figure 4 shows a comparison of the magnitude of the theoretical and analytic transmission coefficient over a range of 0 to 50 GHz. Notice that the agreement between analytic and theoretical is almost perfect. Figure 5 shows a comparison of the phase of the theoretical and analytic transmission coefficient over a range of 0 to 50 GHz, and here also good agreement is obtained.

Next, a trapezoidally modulated sinusoid was used as the excitation in a half space. The frequency of the sinusiod was 1 GHz. As defined by Albanese, Penn, and Medina [4], τ was 10 nanoseconds and the rise time parameter a was (3/4f) seconds. The mesh size was 30,000 cells, the cell size was 1mm, the output point was 1500 cells into the mesh corresponding to a depth of 1.5 meters in water and 20,000 time iterations were used. This is the same case examined in reference [4], Figure 6(b). Although numerical comparisons cannot be made, there appears to be good agreement between the FDTD generated output shown in Figure 6 and the plot of Figure 6(b) in reference [4]

Finally, a comparison was made to determine what effect the cell size had upon accuracy. While the magnitude of precursors cannot be easily determined, we can calculate the theoretical magnitude of the
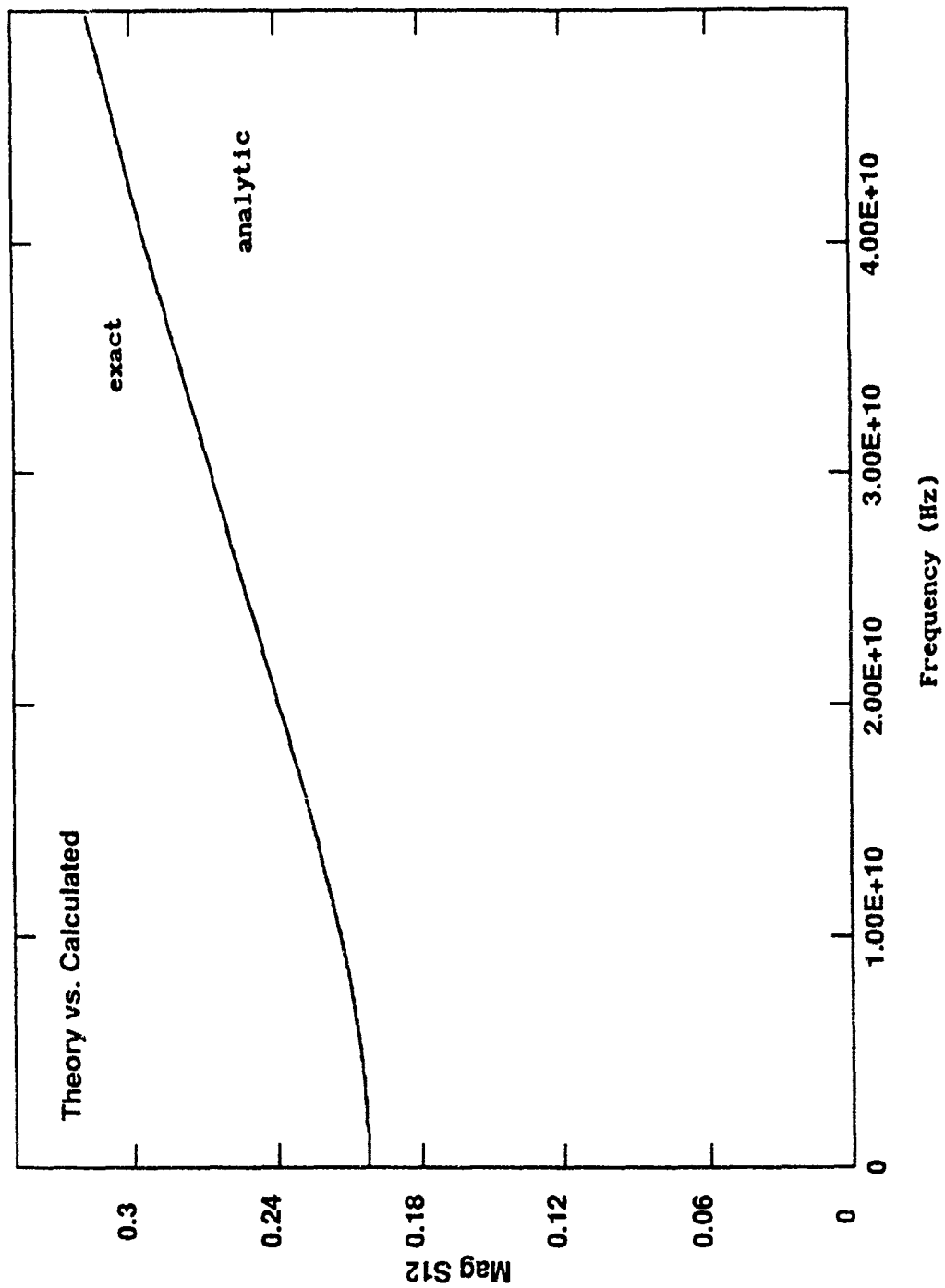
Figure 4. Comparison of the Magnitude of the Analytic and Theoretical Transmission Coefficient.
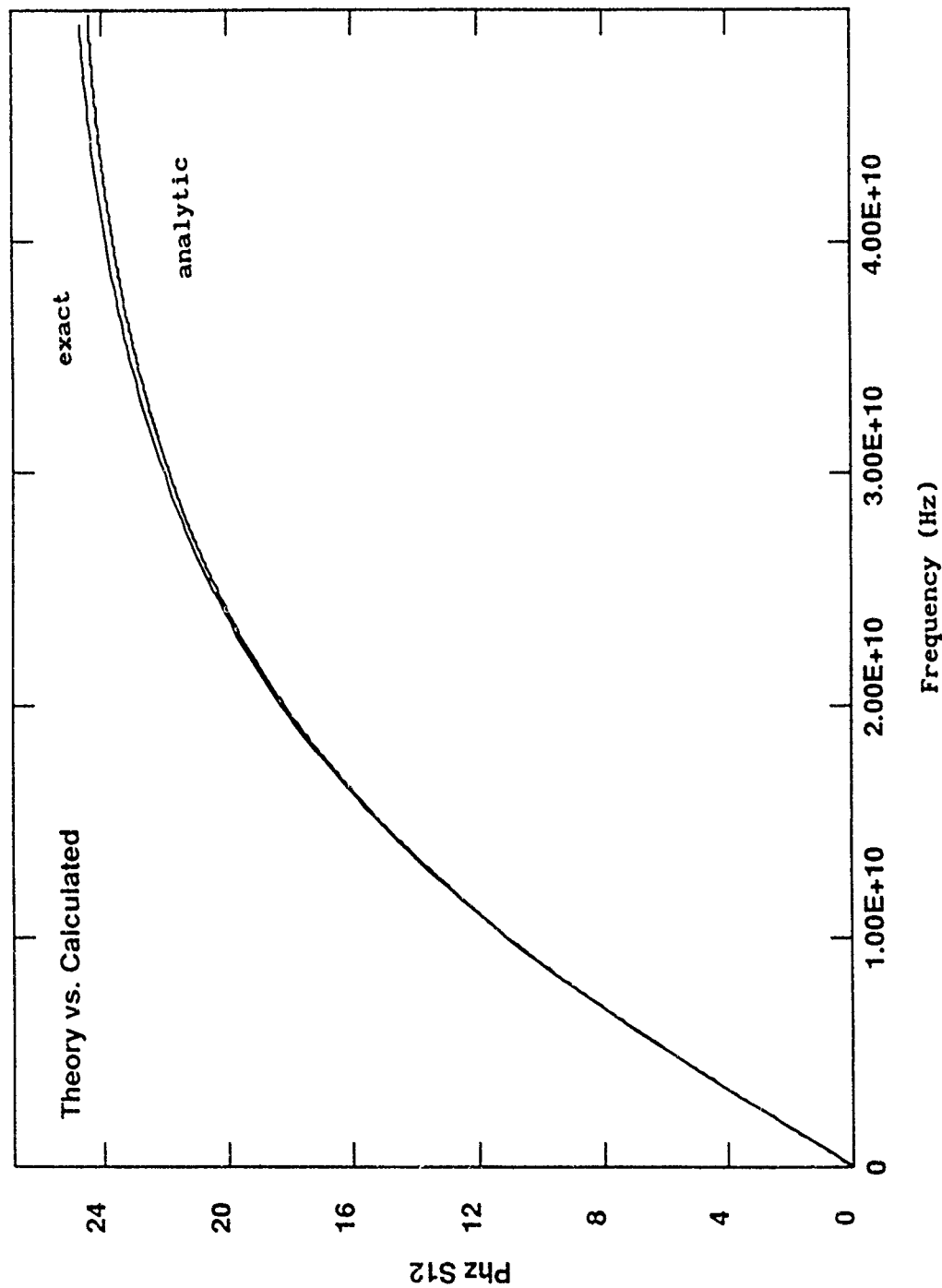
Figure 5. Comparison of the Phase of the Analytic and Theoretical Transmission Coefficient.
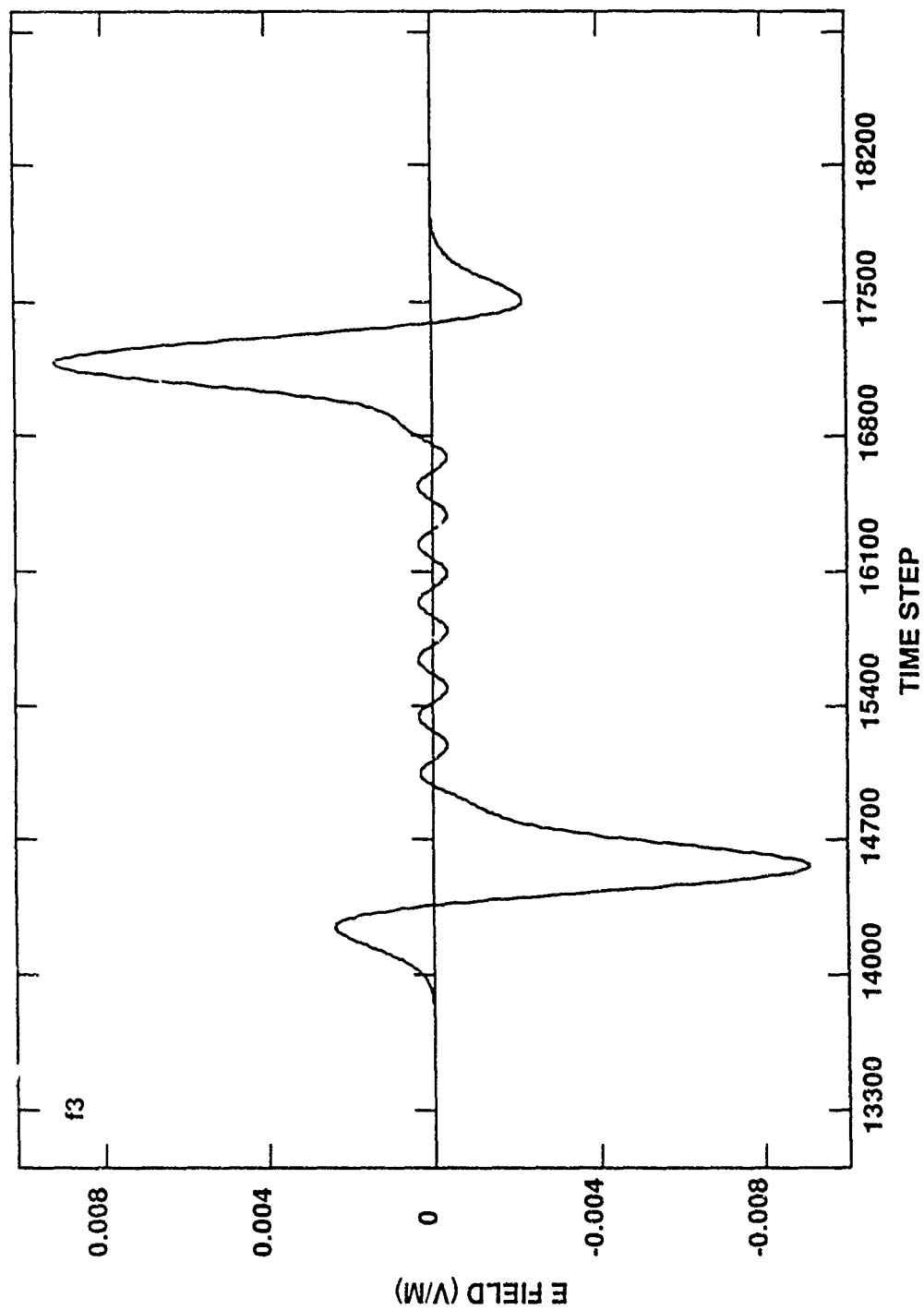
Figure 6. Plot of the Response for a Trapeziodally Modulated Sinusiod.

carrier signal. The table below lists the percent difference between the magnitude of the theoretical and analytic carrier signal for different values of cell size and media depth. A half space was used, with the excitation function a 10 GHz sinusoid modulated by a 1 nanosecond square pulse.

Table 1

Cell Size verses Accuracy

d (mm)	% diff dx=50μ	% diff dx=100μ	% diff dx=200μ	% diff dx=300μ	% diff dx=400μ	% diff dx=450μ
0.1	1.7	2.7	3.1	3.7	4.4	6.0
2.7	1.2	0.7	0.1	1.2	2.0	2.0
4.2	0.6	0.5	3.1	5.4	0.4	6.9
5.7	0.0	1.9	5.2	8.9	11.9	14.3
9.6	1.5	5.3	12.0	20.3	27.8	30.6

As a rule, for any accuracy to be obtained using the traditional FDTD technique the following inequality must hold true

$$\frac{dx}{\lambda} \lesssim 0.1$$

where dx is the cell size and λ is the wavelength in the material. Solving this equation for the case used to generate the data for Table 1, the inequality yields dx < 300μ. Notice that fairly good agreement is obtained for values of dx below 300μ, and it is interesting to note that some accuracy is obtained even with dx being 450μ.

Lorentz Media

A second-order (Lorentz) dispersion can be specified by

$$\varepsilon(\omega) = \varepsilon_\infty - \frac{\omega_0^2(\varepsilon_s - \varepsilon_\infty)}{\omega^2 + 2j\omega\delta - \omega_0^2} = \frac{D(\omega)}{E(\omega)} \qquad (8)$$

where $\varepsilon_s = \varepsilon(0)$, $\varepsilon_\infty = \varepsilon(\infty)$, ω_0 = resonant frequency, and δ = damping

coefficient [2]. Reference [2] models the Lorentz media using a differential approach, which was implemented by Fred German (see his final report). I attempted to model a Lorentz media using the convolution integral approach.

Taking the Fourier transform of equation 8, it can be written in the form

$$D(t) = \varepsilon\infty \, E(t) - E(t) \otimes F^{-1} \left| \frac{\omega o^2 (\varepsilon s - \varepsilon\infty)}{\omega^2 + 2j\omega\delta - \omega o^2} \right| \qquad (9)$$

Taking the Fourier transform of the last term of equation 9, and defining $y = sqrt(\omega o^2 - \delta^2)$, yields

$$\frac{\omega o^2 (\varepsilon s - \varepsilon\infty)}{y} \, e^{-td} \, sin(ty) \qquad (10)$$

Reference [1] outlines the steps for performing the time-domain convolution, with the only necessary change being a new time-domain susceptibility function described by equation 10.

For the convolution integral approach to be practical, the discrete integral must utilize recursive techniques. Integrating equation 10 yields, in a form that can be used for recursion

$$(\varepsilon s - \varepsilon\infty)Re(\, e^{-td}e^{jty}(j\delta/y -1)) \qquad (11)$$

where this result would be evaluated between time $m\Delta t$ and $(m+1)\Delta t$.

Several difficulties were encountered trying to implement this algorithm.

The first problem is that the interface of a half space problem is not stationary. This is probably due to the frequency dependence of the dispersive media. This results in an unstable system. The instabilities are eliminated by defining the electric field at the interface in terms of an average of εs and $\varepsilon\infty$. While this is a

sufficient condition to eliminate instabilities, it is possible that this condition is not entirely adequate. Further research is required.

The next problem was in the convolution integral itself. Due in part to computer error, but most likely to something else as yet undetermined, a correction factor for the integral was required. This correction factor was based on the observation that the recursive integral seems optimized for particular values of Δt, ωo, and δ. Changing these parameters changes the accuracy of the integral in a nonlinear fashion.

The algorithm was implemented and was able to generate both Sommerfeld and Brillouin precursors. However, the magnitudes of the precursors were wrong. Time expired before further research could be done.

CONCLUSIONS

In comparisons between second-, fourth- and sixth-order accuracy in the FDTD algorithm, the fourth-order FDTD algorithm appears to be the most accurate. Little or no improvement is noticed using sixth-order accuracy over fourth-order accuracy.

For dispersive media, the convolution integral approach works very well for modeling Debye media, but as yet is inaccurate for modeling Lorentz media. Problems encountered for the convolution approach to modeling Lorentz media include the 'floating boundary' problem, and the nonlinear error involved in recursive integration. However, results indicated that with further research it should be possible to model a Lorentz media using the convolution integral approach.

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THE EFFECT OF HYPERBARIC OXYGENATION ON MUSCLE REGENERATION FOLLOWING TOXIN INDUCED NECROSIS

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Abstract

Skeletal muscle's viability and its capacity to recover from injury are tied to the amount of oxygen present in the tissue. Hyperbaric oxygenation therapy (HBO) has been shown to reduce the amount of muscle necrosis and thus maintain viability during acute conditions of ischemia and compartmental syndrome. It is not known, however, if HBO will continue to slow the rate of necrosis under more chronic conditions or if it will accelerate the recovery from a necrotic condition. The purpose of this project was to determine if the rate of muscle regeneration or recovery from a chemical toxin induced muscle necrosis can be accelerated by HBO.

Introduction

When a person spends an extended amount of time living in an untamed outdoor environment such as those encountered in wartime activity or maneuvers, they are at a greater risk of being attacked by a venomous animal. In addition to the possibility of death from such an attack, envenomation can cause serious injury to the body since most venoms exhibit vasoconstrictive, thrombotic, hemolytic, neurotoxic, and necrotizing activity. Interestingly, the tissue pathology arising from these deleterious activities of venoms is quite similar to that which is seen in cases of tissue ischemia and compartment syndrome. Since compartment syndrome and ischemic based

myonecrosis respond well to hyperbaric oxygenation therapy (HBO) (1), it would appear that HBO would be indicated for the treatment of evenomation. Unfortunately, little research has been done on the use of HBO and evenomation, and that which has been done is open to question. For instance, there are clinical studies (such as Workman et al (2) with pit viper evenomation and Svendsen (3) with brown recluse spider evenomation) which suffer from the lack of a control group, and there are controlled studies (such as Stolpe et al (4) with pit viper evenomation) which are inconclusive due to lack of venom and antivenin dose/response knowledge for the animal model used. Therefore an ideal research project concerning the efficacy of HBO on evenomation induced myonecrosis would entail using a control group and a venom with characterized myonecrotic activity. The cardiotoxin purified from the venom of Naja mocambique mocambique has been used in research involving muscle regeneration (5). This toxin when applied directly to mouse muscle at a 10 uM concentration will induce myonecrosis without causing death or destroying the muscle's innervation (5). Also, the myonecrotic activity is at a low enough level that muscle regeneration to a normal condition is complete two months post-administration (5). Thus it appears that this toxin would be a good choice as the toxic agent for research concerning the efficacy of HBO on venom induced myonecrosis.

Therefore, it was the purpose of this research project to evaluate the effect of HBO on the recovery of skeletal muscle following a toxin induced myonecrosis. It was hypothesized that HBO would help the muscle regenerate quicker than it would under non-treated condi-

tions.

Experimental design and methods

Animals. Thirty-six adult male rabbits served as the experimental model. The rabbits were divided into four groups of nine rabbits each.

Evenomation Procedures. To create the toxin injury, the rabbits were anesthetized with ketamine HCL (35 mg/kg I.M.) and xylazine (5 mg/kg I.M.). The right gastrocnemius was then injected with pure cardiotoxin, 10 uM Naja mocambique mocambique cardiotoxin (Sigma Chemical Co., St. Louis MO) in 0.9% NaCl solution. The muscles were injected in ten sites each with 0.1 ml of the cardiotoxin solution. Six rabbits randomly selected from each group were injected each until all rabbits had been injected.

Experimental treatments. Each group of nine rabbits was randomly assigned to one of four treatments. The animals in three of the groups were subjected to HBO treatments, while the other group served as the control. Group 1's HBO treatment was similar to the protocols shown by Nylander (2) and Strauss et al (3) to be effective in the acute treatment of crush injuries. For the long term care, the protocol was adjusted so that it simulated the general treatment protocol currently used by USAF Al/AOH to treat the majority of medical problems seen in human patients. Specifically, the treatment protocol consisted of 90 minutes of breathing 100% oxygen at a pressure of 2.4 ATA (45 fsw). The descent to 2.4 ATA took five minutes, and the ascent to normabaria following the treatment lasted 15 minutes. Thus, the animals were in the hyperbaric chamber

a total of 110 minutes each treatment period. Temperature within the hyperbaric chamber was maintained near 22° C by venting a continuous flow of 100% O_2 through the chamber. This venting procedure also prevented the build-up of expired CO_2. The venting flow rate was set at a flow which ensured that the oxygen content, as determined by a polargraphic oxygen analyzer, of the vented gases was greater than 95%. The treatments were initiated 6 hours post-operative and continue twice daily five days a week thereafter. The twice daily sessions will consist of one A.M. session and one P.M. session with a minimum four hour interval between sessions. Group 2 received the same treatment protocol as Group 1 with one modification. Instead of breathing 100% O_2, Group 2 breathed a mixture of 8.5% O_2 and 91.5% N_2 (a mixture which is comparable to breathing normabaric atmospheric air.) Group 3 also received the same treatment protocol as Groups 1 & 2, except in their case they were expose to 100% O_2 at 1 ATA. Finally, Group 4 experienced the same chamber protocol, but in their case the rabbits breathed normabaric atmospheric air (1 ATA, 21% O_2, 0.03% CO_2, 79% N_2).

As indicated above, the groups receiving HBO received these treatments 5 days per week. The treatments for each group proceeded as outlined above for a period of 4 weeks (or 20 HBO treatment days), at which time the animals were euthanatized in the order which they were injected (six animals per day and the poisoned muscle harvested for analysis.

Tissue Harvest. As mentioned above, crushed muscle was harvested for analysis following 4 weeks of treatment. The muscle har-

vest occurred 12-16 hours following the last treatment session (i.e.

harvesting began in the morning of the day immediately following the

20th day of treatments). The animals were anesthetized with keta-

mine (35 mg/kg I.M.) and xylazine (5 mg/kg I.M.) and the muscle

exposed. Prior to the harvest of the crushed muscle for morphologi-

cal and biochemical analysis, the muscle's twitch and fused tetanus

tensions was recorded. The muscle was freed from the surrounding

connective tissue, and the gastrocnemius portion of the

Achilles tendon severed and attached to the lever arm of a force

transducer. The muscle was held at its normal resting length by

securing the lower hindlimb via steel pins placed through the knee

and ankle joints. The muscle was then stimulated directly via plati-

num electrodes placed on each side of the muscle nerve. Both twitch

and a fused tetanic tension were recorded via the force transducer

to an oscilloscope. To obtain a muscle twitch, the muscle was stimu-

lated by a single 10 V square wave pulse 2.4 msec in duration. Fol-

lowing the twitch, the muscle was allowed to recover for 1 minute,

after which maximal tetanic tension was recorded. Maximal tetanic

tension was elicited using a 1 train/sec for 500 msec with 100 im-

pulses/train stimulation regime. Again, the muscle recovered for one

minute, and then the muscle removed. Upon removal, the muscle was

trimmed of connective tissue, weighed, and a portion belly cut out

and placed in 10% formalin buffer. The rest of the muscle was

quick frozen in isopentane cooled to below -80° C and stored at

-75° C. These procedures were then repeated with the contralateral

left gastrocnemius muscle. Following the removal of the contralater-

al muscle, the soleus, diaphragm, heart, trachea, sciatic nerve, and liver were removed and frozen for analysis in conjunction with other projects.

Tissue analysis. The formalin fixed muscle pieces were to be paraffin embedded, sectioned, and stained with hematoxylin and eosin (H&E) (6) to determine muscle pathology and with Masson trichrome (6) to highlight intra-muscular collagen by the pathology personnel of AL/OEV. Additional muscle pieces were designated for analyses to determine enzymatic activity. The enzymes to be assayed and the procedures used were as follows: citrate synthase, Srere (7); adenylate kinase, Bergmeyer (8); glyceraldehyde 3-phosphate dehydrogenase, Lowry and Passonneau (9); hexokinase, Uyeda and Racker (10); and glucose 6-phosphate dehydrogenase, Wagner et al (11).

Statistics. An analysis of variance was used to compare the differences between the right and left muscles within and between groups.

Results

The gastrocnemius muscle weights for the poisoned limb (right) and the nonpoisoned limb (left) for each treatment group are shown below in Table 1. AS can be seen in Table 1 there was no difference in muscle weights between legs or across groups. Due to the magnitude of the tensions for the majority of the muscles exceeding the resolution capabilities of the available force transducers, the muscle tension measurements were discarded and are not presented here. Visual inspection of the muscles found no evidence of muscle necrosis. This observation, however, can not be verified by the histo-

chemical stains and enzyme analyses as these procedures can not be completed in time to make the deadline for this report.

Table 1. Gastrocnemius muscle weights.

Treatment	Left	Right
2.4 ATA 100% O2	10.1 ± 1.1	10.0 ± 1.0
2.4 ATA 8.5% O2	9.7 ± 1.2	9.8 ± 1.1
1 ATA 100% O2	10.3 ± 0.6	10.1 ± 0.4
1 ATA 21% O2	10.2 ± 0.7	10.5 ± 0.5

Values are means ± S.D.

Discussion

The above data derived from the excised gastrocnemius muscles indicates that the experiment did not accomplish its intended goal. Apparently, the desired toxin-induced muscle necrosis did not take place to the extent which was desired, if it took place at all. There are at least three possible reasons for the low necrosis. First, previous work (5) using the naja mocambique toxin was done in mice, and therfore it is possible that the rabbit physiology differs enough that the sucessful dosage in mice is not concentrated enough for the rabbit model. It is also possible that the dosage was adequate, but that the recovery rate from the toxin is much more rapid in the rabbit than it is in the mouse. Finally, it is possible that the toxin used had become inactive or denatured thus losing its necrotic capabilities.

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DEVELOPMENT OF COMPLIANCE / RESISTANCE ELEMENT RELATIONSHIPS FOR USE IN DESIGNING HEMODYNAMIC MODELS OF SECTIONS OF THE HUMAN CIRCULATORY SYSTEM

Dora Y. Hsie

Abstract

In this study, a flexible compliance/resistance system for designing hemodynamically accurate portions of the human circulatory system is designed and tested. A full factorial design is used to measure the effects of resistance, water/air capacitance, and flow rate. In this system, pressure and velocity are monitored up and downstream using Omega PX236 pressure transducers, Millar high-fidelity micromanometers, and hot film anemometers. Omega PX236 response is found comparable to the Millar high-fidelity micromanometers. Preliminary attempts to calibrate Doppler velocity crystals using a hot film anemometer were marginally successful. The two signals are qualitatively very similar but scaling problems prevent quantitative comparisons. Satisfactory responses are obtained in Doppler velocity crystal testing using 0.023" wall thickness plexiglas tubing with water seeded with 7.5 g of corn starch per liter.

INTRODUCTION

Gravitational loss of consciousness (GLOC) has cost the military millions of dollars in loss of aircraft and the lives of many highly trained pilots. GLOC occurs in many high speed tactically advantageous aerial combat maneuvers. Gravitational forces on the pilot of 9 to 15 G for 3 to 7 seconds can result in the pilot's loss of consciousness and subsequent loss of craft and life.[1]

A dynamic mechanical/hydraulic model of the human circulatory system would aid in the understanding of GLOC by providing a physical means of very high G-testing without risking lives and aircraft. The model could also be used to verify computer models. To create such a model of the entire circulatory system, individual sections of the body must be hemodynamically simulated. The aim of this study is to create a tool to aid in designing hemodynamically accurate models of hemodynamically significant sections of the human body.

A modified *Windkessel* model is placed in series with a bellows pump which provides pulsatile flow to the system. (See Figure 1) In order to create a hemodynamically accurate model, compliance and input impedance characteristics must be accurately modelled. Compliance is defined as a delta pressure induced change in volume divided by the change in pressure itself, Liu et al.[2] Input impedance is defined by Nichols and O'Rourke[3] as (Z_i), "the relationship between pulsatile pressure and pulsatile flow in an artery feeding a particular vascular bed." $Z_i = P/Q$. By monitoring

velocity and pressure upstream and downstream of the model as system elements are varied, the relationships between the input impedance, compliance and other parameters may be determined.

In addition to the above objective, Doppler velocity crystals and the Omega Series PX236 pressure transducer are tested for their suitability for later experiments.

PROCEDURE

Design of the model

To be a useful design tool for hemodynamic modelling of sections of the human circulatory system, resistance, flow rate, compliance, and capacitance need to be adjustable factors. In addition, pressure and velocity responses need to be monitored for each change.

The following system was constructed to meet these requirements. A watertight box of 1/2" plexiglas surrounds the compliant system. The box is partially filled with water leaving a 0" or a 2" air pocket confined at the top of the box to provide two levels of capacitance. Two compliant members, a 9" length of 3/4" diameter rubber tubing and a 5/8" diameter Penrose latex drain, are studied. A resistor constructed from a kidney dialysis filter is located on the downstream side of the compliant tubing. Several resistance levels are obtained by placing different sized orifices inside the resistance element.

A bellows pump provides the pulsatile flow to simulate hemodynamic circulation. A raised reservoir (approx. 27" above the

system) placed in series with the bellows pump and the compliance system provides the system head pressure. Velocity and pressure are monitored upstream and downstream of the compliance system. Hot film anemometers are used to monitor velocity. Omega transducers and high fidelity Millar micromanometers are used to monitor pressure. Velocity and pressure signals are recorded on a TEAC MR-30 cassette data recorder at a tape speed of 4.8 cm/sec. Equipment is further discussed in the equipment section. (See Figure 2)

Equipment

Pulsatile bypass pump

A pulsatile source is required to accurately model the circulatory system. A pulsatile cardiac aortic balloon assist pump was tested for its suitability. The pump has both a vacuum and pressure mode which may be adjusted for longer/shorter proportional input and output durations and frequency. This air pump is connected to a waterproof airbag which was placed in an airtight, water-filled container. Water moves into and out of the chamber through two one-way check valves. The changing volume of the airbag is the driving force for water movement causing an increase in pressure when filled, pushing water out of the chamber, and a decrease in pressure on deflation, drawing water into the chamber. Preliminary results show that pulsatile flow is very difficult to control and some regurgitation occurs. (Figure 3.)

Bellows pump

A positive displacement bellows pump from Gorman-Rupp Industries model 15076-003, X-126, T-009 is used to provide the pulsatile flow needed to simulate natural blood flow. The pumping frequency is approximately 1.5 Hz at 115 V. Flow rate is changed by adjusting the stroke volume. Frequency remains constant. Flow rate is calibrated by measuring the volume pumped over time. (See Figure 4)

Calibration of Hot Film Anemometer

TSI hot film probe model #1210-60W is used to measure the time varying velocity of the water. This sensitive system places a voltage over a sensing wire and indirectly measures the rate of heat removal from the wire by the fluid. This rate of heat removal is then correlated to the fluid velocity. To provide known calibration velocities, a 27 cm diameter disk with two concentric grooves (11.5 cm and 24 cm diameter) filled with the fluid to be tested in the system is placed on top of a turntable. The turntable rotates at 45 rpm and 33 rpm. Using both diameters and both rotational speeds, four known calibration velocities are obtained.

Calibration of Pressure Transducers

To measure the pressure upstream and downstream of the compliance system, an Omega PX236 pressure transducer and a high fidelity Millar micromanometer are placed at each position. The

output signals are calibrated through a bridge amplifier. With the system open to atmospheric air zero, the amplifier is balanced for each transducer. A pressure of 200 mmHg is then applied using an air filled syringe as an adjustable pressure source for the closed system. A mercury manometer is used to measure the pressure applied to the transducers during the calibration procedure.

Evaluation of Omega transducers

Omega transducers are located up- and downstream of the compliance system. Millar micromanometers which have transducers at the tip are located in close proximity. Pressure responses of the two types of transducers are compared visually on a display and recorded on the TEAC MR-30. The visual comparison shows very similar qualitative responses.

Compliance of Windkessel

The compliance of bicycle tire rubber innertube and latex tubing is tested by measuring the change in volume of the tubing due to a change in pressure. The volume change is determined by measuring the water displaced as pressure inside the tube is induced with a syringe.

Testing of the compliance test system model

The purpose of "design of experiment" is to allow the experimenter to obtain the most information from the fewest number of tests. One method that has been successful for the Japanese

industry is the Taguchi method of design. This method is a form of fractional factorial design and requires the fewest number of tests.[5] However, it is most effective when either critical information is already known about the effects of the factors, or a large number of factors (>5) are being tested.

The parameters we chose to vary are : resistance, air pocket size, and flow rate (two levels for each factor) for 3/4" diameter bicycle tubing and 5/8" diameter Penrose latex drain tubing. Since only three factors were varied, a full factorial design was chosen to get more complete information. Resistance was tested with only the dialysis resistor and with the smallest diameter disk in place; the water capacitance was varied between 2" air pocket and 0 air pocket. Two flow rate were tested 2.3 l/min and 3.3 l/min. (See Figure 5 for orthogonal array of experiment.) Each array was tested in random order and the set repeated 5 times to achieve 95% confidence. Velocity and pressure responses were recorded on the Teac MR-30 7-channel cassette data recorder with a frequency response of 1.25 kHz (Tape speed: 4.8 cm/sec).

Velocity measurement with Doppler

Ultrasonic Doppler is another means of monitoring fluid velocity in a tube. Its feasibility for our needs was tested on a plexiglas tube in a simplified system. (See Figure 6) This system used the bellows pump as a source of pulsatile flow. Responses of the Doppler were compared to those of the hot film anemometer. A reservoir at varying heights provided for a range of DC flow

velocities. Doppler velocities were calibrated against the hot film anemometer measurements. The hot film probe was calibrated by the method as described earlier. The flow rate was also calculated by collecting the exiting water into a graduated cylinder and measuring the volume collected over time. Seeding material, necessary for crystal response, were also tested.

RESULTS

Evaluation of Omega transducers

Although the Omega transducers and the Millars were not placed in precisely the same position (See Figure 1), qualitative observation indicates that the Omega transducers produce very similar responses to the Millar micromanometers. When the signals are juxtaposed, few differences are visible. Spectral analysis of the two signals will be done to determine quantitatively if there are any significant differences.

Tubing compliance

Compliance testing of the bicycle and latex tubing show the change in volume over pressure remains constant at approximately 3.2×10^{-2} cc/mmHg +/- 40%. Latex compliance appears to increase linearly with a slope of approximately 2×10^{-2} units. (Figure 7)

Compliance system

Velocity and pressure data were recorded on a TEAC MR-30 cassette data recorder at 4.8 cm/sec, 1.25 kHz resolution. An experimental procedure based on a full factorial orthogenal array with two levels of resistance, air pocket size, compliance and flow rate for bicycle and latex tubing. The array was repeated 9 times with trials conducted in random order for 95% confidence. (Figure 5)

Ultrasonic Doppler crystal

Velocity signal responses of the Doppler crystal and the hot film anemometer were recorded on a stripchart recorder. While they were qualitatively very similar, the Doppler signal contained considerable high frequency noise which was not present in the hot film signal. The Doppler signal should be low-pass filtered before it is quantitatively compared with the hot film signal. 7.5 grams of corn starch per liter of water provides sufficient seeding for the Doppler crystal. However, tygon tubing and 1/8" plexiglas do not adequately pass the Doppler signals; 0.023" plexiglas works well.

CONCLUSIONS AND RECOMMENDATIONS

The Omega PX236 pressure transducers are suitable for the needs for the measuremerts of the design tool required.

Qualitatively, the apparatus appears to be a legitimate design tool for designing compliance systems simulating parts of the body. However, the compliance data recorded on the TEAC MR-30 need to analyzed on data analysis software such as DaDisp for quantitative conclusions. These results should then be verified by changing a factor, such as tubing, and predicting the results. When the compliance system is found reliable, body parts can then be designed.

The ultrasonic Doppler crystal showed comparable velocity responses as compared to the hot film anemometer. Additional calibration work is needed to fully quantify the time varying pulsatile velocity profiles in the tubing.
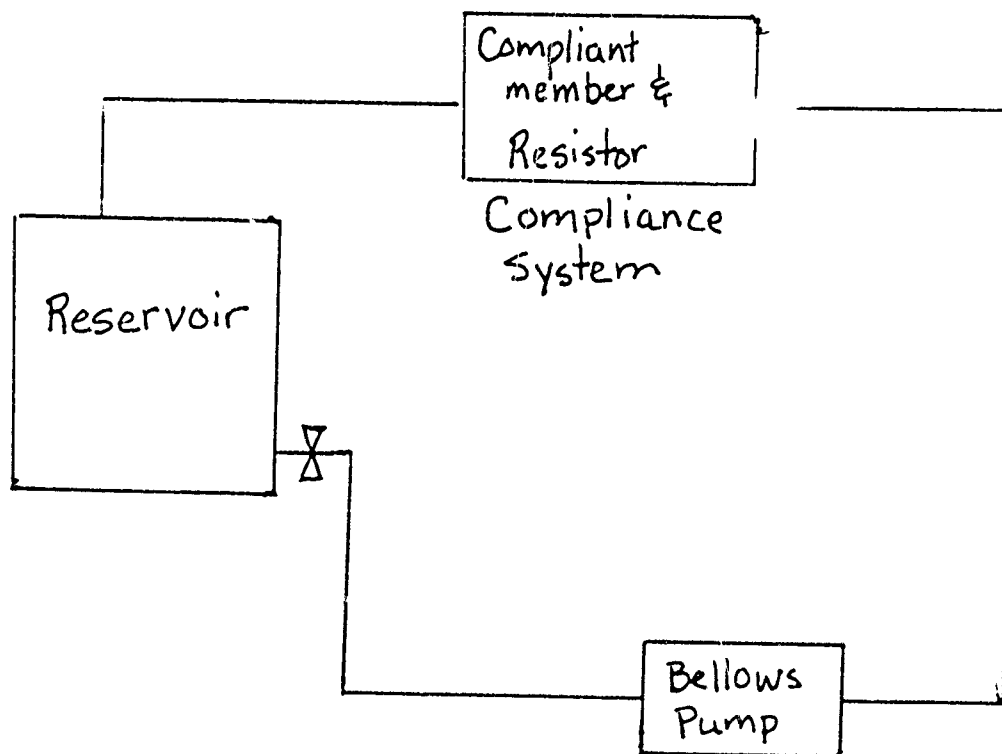
Figure 1 : Block Diagram of
Test system
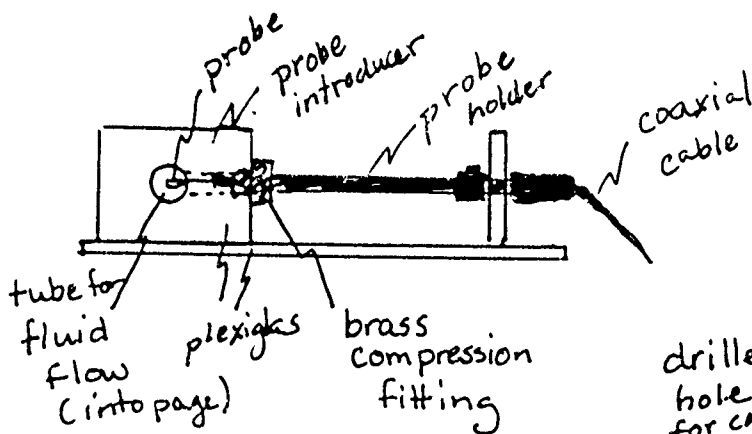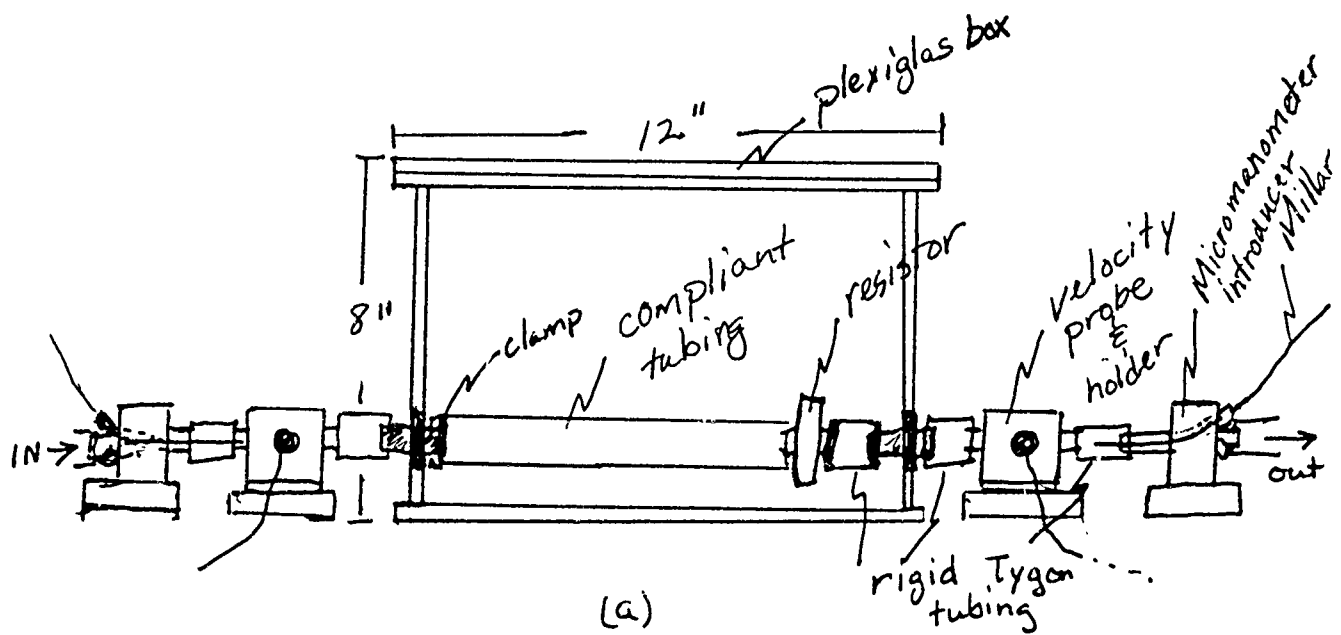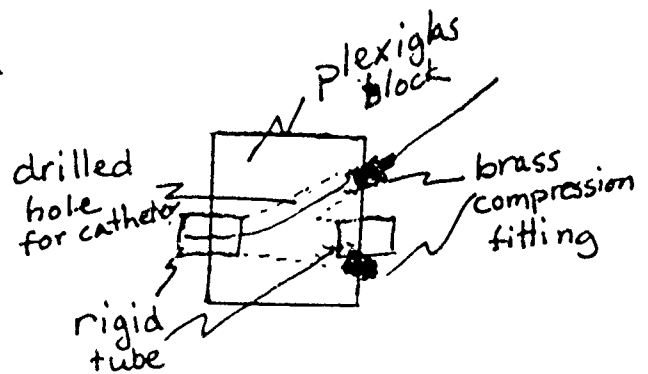
Figure 2 : Compliant system

(a) system with monitoring equipment

(b) hot film anemometer (velocity)

(c) Millar micro manometer & Introducer

to pulsatile bypass pump

non-rebreathing bag

14"

radiator hose

OUT

IN

aluminum

pvc male adapter

13"
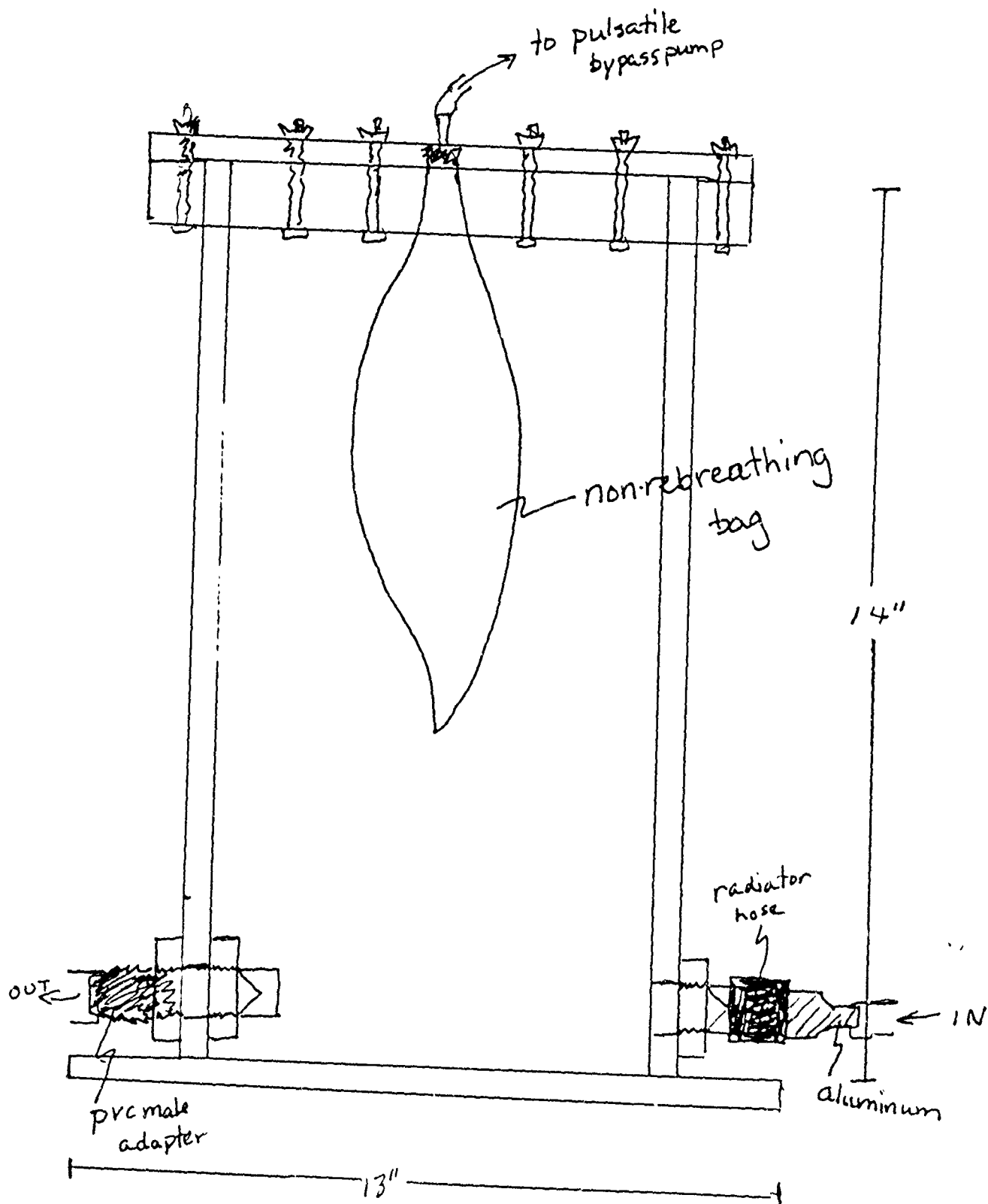
Figure 3 : Pulsatile pump system

Calibration of Bellows Pump
Figure 4
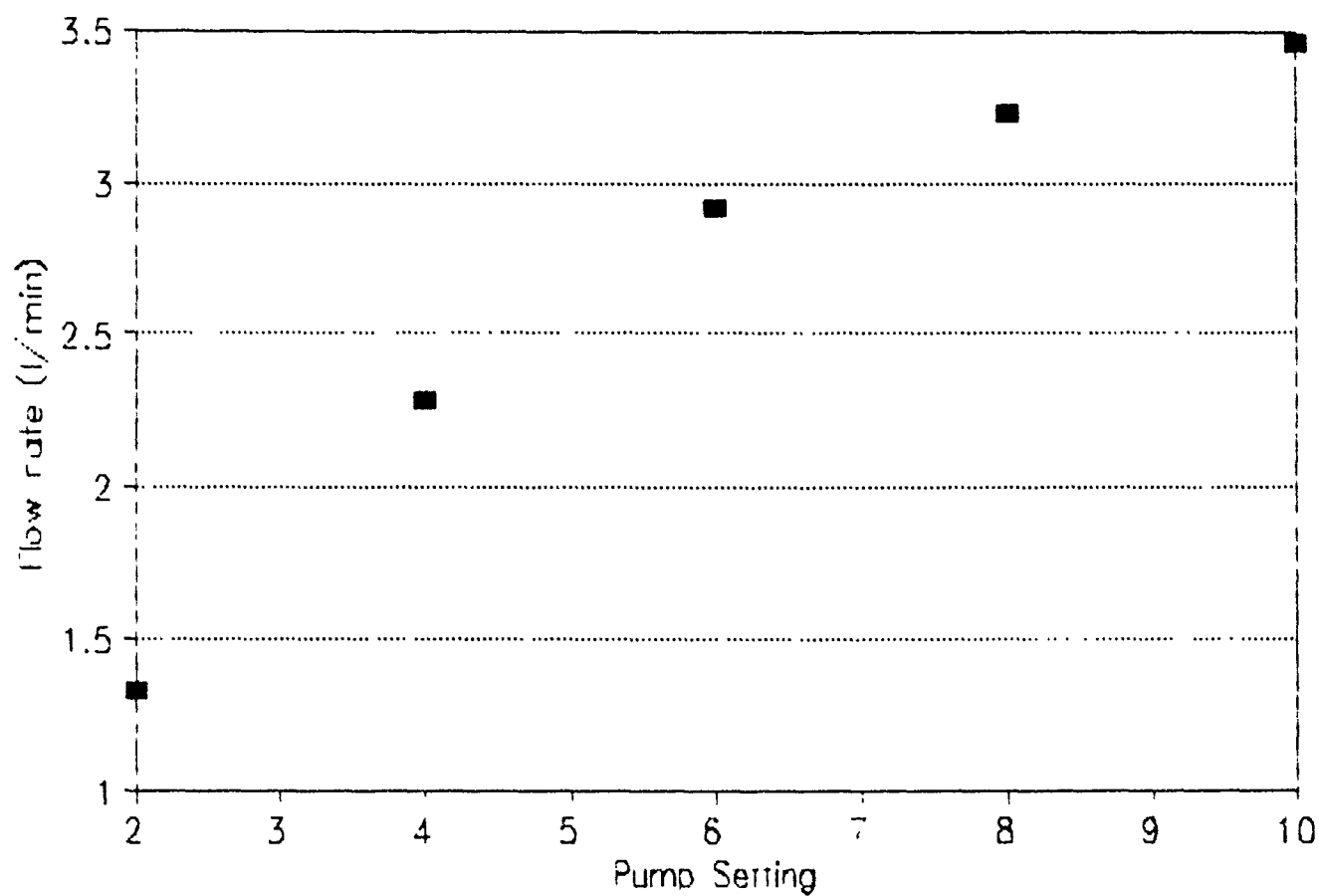
Full Factorial Design of Experiment

Resistance A

$n = 2^3 = 8$

Air Pocket B

$n_r = \dfrac{32}{n} + 1 = 5$

Flow Rate C

	A	B	C	Order of Tests (Random)				
				Y_1	Y_2	Y_3	Y_4	Y_5
1	−	−	−	6	5	8	2	4
2	−	−	+	7	4	2	5	2
3	−	+	−	3	2	5	3	6
4	−	+	+	8	8	1	4	1
5	+	−	−	4	6	6	1	8
6	+	−	+	2	7	3	7	5
7	+	+	−	5	1	7	6	6
8	+	+	+	1	3	4	8	3

A + = small resistor (large resistance)
  − = ∅ resistor (none)
B + = 2" air pocket
  − = ∅ air pocket
C + = flow rate of 8
  − = flow rate of 4

Figure 5 : Orthogonal Array of Experiment
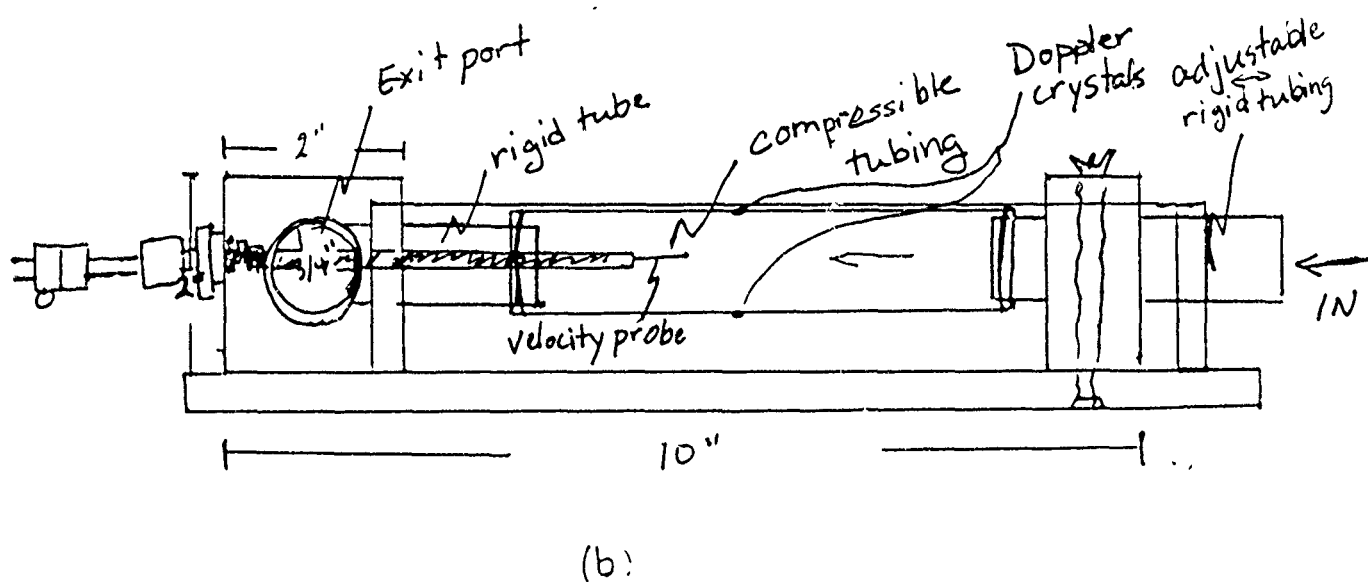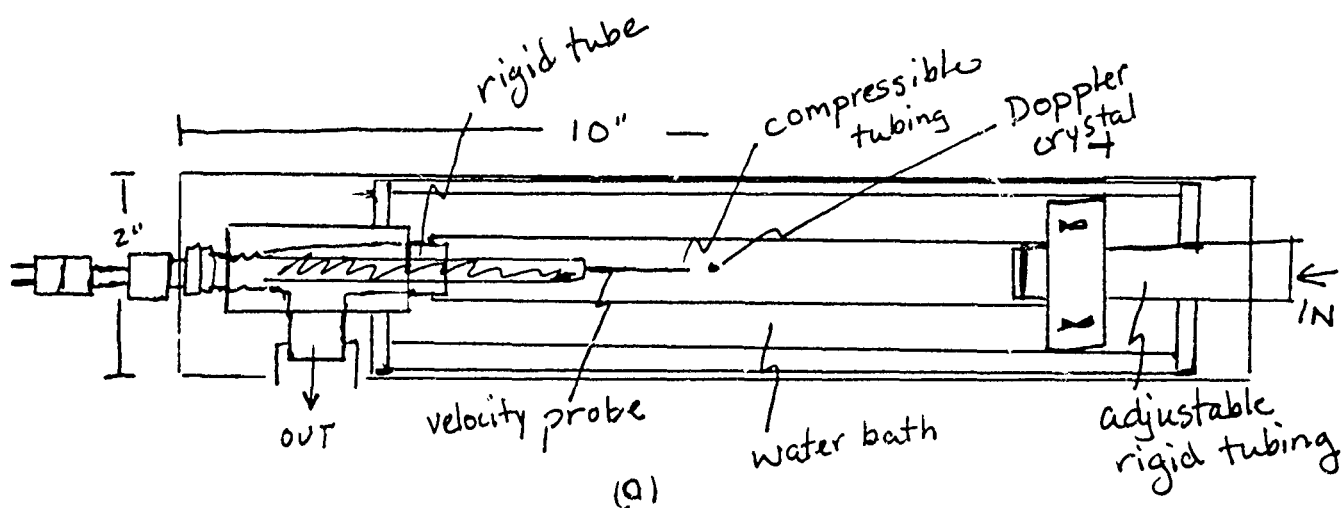
Figure 6 : Doppler crystal Test
apparatus
(a) Top
(b) Side

Figure 7. Compliance Testing:
Bicycle and Latex Tubing
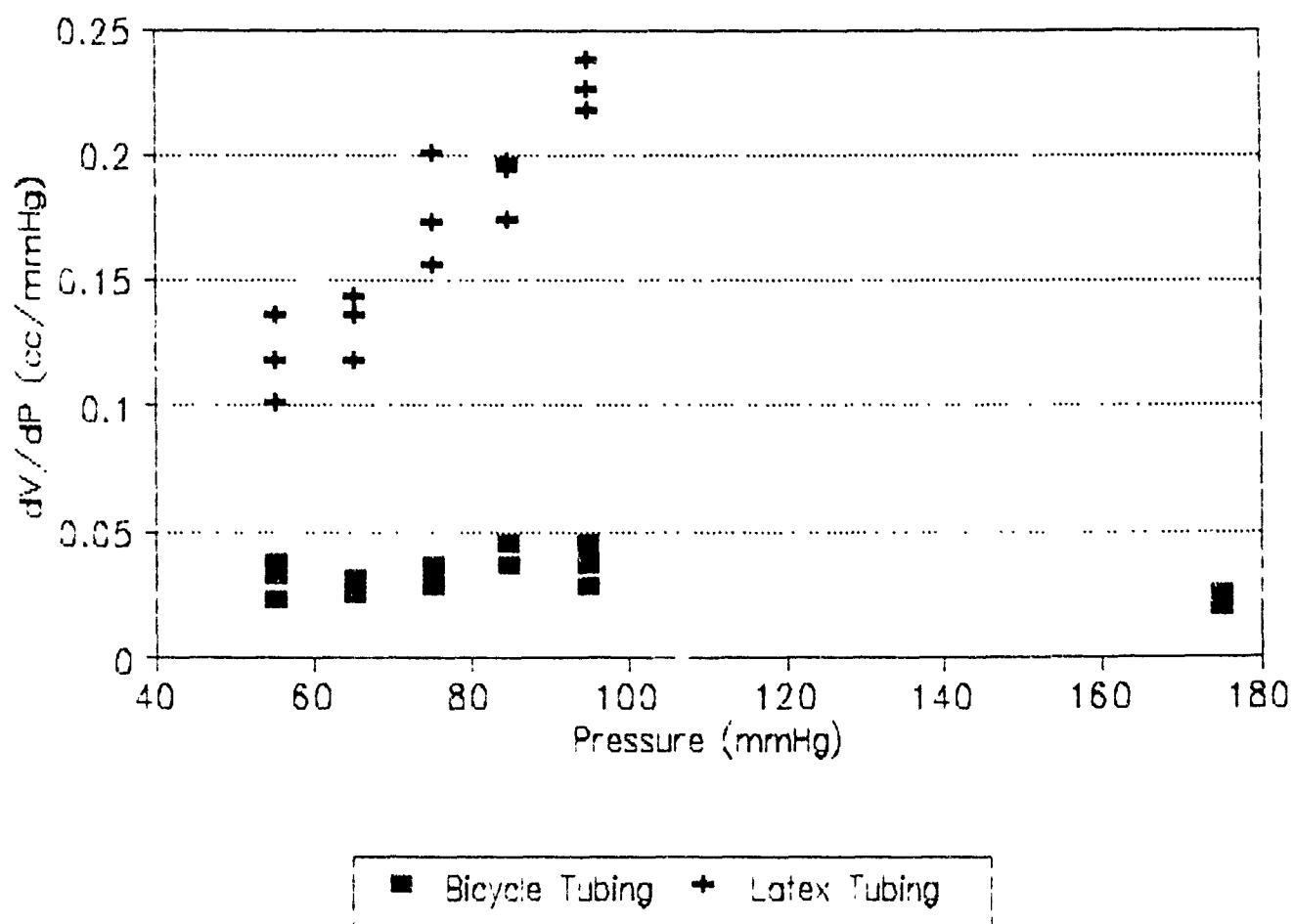
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CIRCULATORY SHOCK DURING SUPERFICIAL HEATING WITH MILLIMETER WAVES

Sarah Miller, Research Associate

Ketamine-anesthetized Sprague-Dawley rats were exposed to
35 GHz continuous-wave radiofrequency radiation (RFR) in "E"
orientation at an average specific absorption rate of 13 W/kg
(power density=75 mW/cm^2) During left lateral irradiation, colonic
(T_c), left subcutaneous (T_s), tympanic, and tail temperatures, ECG;
arterial blood pressure, respiratory rate, and superior mesenteric
blood flow were continuously monitored by a PC computer-based
system Upon initiation of irradiation, the T_s began to increase
immediately, however, there was a 3-4 minute delay before T_c began
to increase, indicating that circulatory transfer of heat from the
periphery was responsible for internal heating. During the course of
exposure, the T_s increase was significantly greater than the T_c
increase (36-50°C vs 36-39°C, respectively) Heart rate increased

monotonically during irradiation, while mean arterial blood
pressure increased initially and then decreased dramatically. Also,
splanchnic blood flow decreased during initial heating and then
increased continuously until death. Simultaneously, blood pressure
decreased at various rates until death. Such a reaction is
characteristic of circulatory shock seen during heat stroke and
terminal exposure to RFR. However, these reactions normally occur
at colonic temperatures of 41.5°C or higher, while in the present
study they occurred at less than 39°C. These results suggest that
extreme peripheral heating, such as occurs during Millimeter Wave
exposure, as well as core heating, can initiate circulatory shock,
possibly by initiating splanchnic vasodilation.

Introduction

Recent development of hardware systems capable of
generating millimete waves (MMW) has spawned interest in the
possible bioeffects and health hazards of incidental exposure At
present, few studies of the patterns of heat distribution and

attendant physiological responses during whole-body irradiation in the MMW frequencies (30-300 GHz) have been reported. Although the pathophysiology of heatstroke has been studied (1), the mechanisms of death due to heat exposure remains a high priority for research.

Cardiovascular responses to heat stress generally persist in spite of administration of general anesthetics (2). The value of the anesthetized rat as a model for studying heat stress responses has been addressed previously by Kielblock et al. (3). Guyton (4) reported that cardiac output regulation in laboratory rats is both qualitatively and quantitatively identical to that in humans. Heat induced mortality curves are also similar in rats and humans (5). Thus, many of the studies of cardiovascular heating, whether due to conventional means or RFR, have involved the rat.

Previous studies (6) have characterized the physiological effects of peripheral heating on cardiovascular, respiratory and thermal changes during lethal irradiation. The drastic drop in mean arterial pressure seen in the aforementioned study has elicited interest in determining its cause. This is the focus of our

investigation.

Since the heart rate was increasing as the MAP decreased, it is likely that the decline is due to a decrease in stroke volume. This response is similar to the cardiovascular shock seen in conjunction with environmentally-induced heat stroke. It is generally agreed that the cardiovascular impairment involves a marked reduction in vascular resistance (7), and blood pooling in the peripheral vasculature (8). It is also generally accepted that in mammals, the main mechanism of heat loss during RF irradiation is through peripheral vasodilation (9). However, under normal circumstances, increased peripheral blood flow will be offset by decreased blood flow to the viscera, so that MAP is maintained.

Thus, the main objective of this preliminary study is to coordinate measurements of splanchnic blood flow with heart rate and blood pressure in order to show a relationship between splanchnic vasodilation and the onset of shock due to peripheral heating.

Materials and Methods

Animals and Physiological Monitoring. Eighteen male Sprague-Dawley rats (Charles River Laboratories), weighing between 385g and 413g (mean ± SEM 400 ± 4 g) were used in this study. Before experimentation, the animals were housed in polycarbonate cages with free access to Purina rodent chow and water, and were maintained on a 12h/12h, light /dark cycle (lights on at 0600) in a climatically controlled environment (ambient temperature 24 ± 1°C).

Animals were fasted for at least 18 hours (free access to water) prior to experimentation. Ketamine HCl (Vetalar), 150 mg/kg i.m., was administered as a general anaesthetic, with supplemental doses administered as necessary during experimentation. This dose level of ketamine has been shown to produce adequate prolonged anaesthesia in Sprague-Dawley rats (10), and results in a stable animal preparation compatible with physiological monitoring (11).

Prior to irradiation, an aortic cannula (Teflon, 28G, I.D) was

installed via the left carotid artery to measure arterial blood pressure (MAP). In addition, in order to monitor splanchnic blood flow (BF), a Pulsed-Doppler flow probe was implanted on the superior mesenteric artery and grounded in the subcutaneous muscle layer of the abdominal cavity. The probe was then secured by stitching a piece of gauze (glued to the leads) in while closing the incision. Before the probe was installed, it was calibrated in room temperature saline solution, and the flow meter was allowed to warm up for 30-45 minutes.

Immediately after surgery, the animal was placed in a plexiglass holder in the RFR exposure chamber. Here a lead II ECG was obtained by use of nylon-covered fluorocarbon leads attached to shielded cables outside the RF field. Respiratory rate (RR) was monitored using a pneumatic transduction method involving a piezoelectric pressure transducer. Temperature was monitored at five sites. left subcutaneous (lateral, mid-thoracic, side facing RFR source) (T_S), right subcutaneous (lateral, mid-thoracic, side facing

away from RFR source) (T_{sr}), right tympanic (T_t), tail (under the skin approximately 2 cm from the base of the tail) (T_{ta}), and colonic (5-6 cm post-anus) (T_c).

RFR Equipment. The continuous-wave RF fields were produced by a model 1325 RF power source (Cober Electronics, Inc.) and transmitted by a model 644 antenna (Narda Microwave Corporation). The exposures were performed under far-field conditions (animal positioned on boresight 115 cm from antenna), and the incident power of the field was determined with an electromagnetic radiation monitor (model 8616, Narda Microwave Corporation), employing a model 8623 probe. During exposures, the generator power was monitored constantly with a model 432-B power meter (Hewlett-Packard). Irradiation was conducted in an Eccccorb RF-shielded anechoic chamber (Rantee, Emerson Electronic Co.). The temperature and relative humidity in the chamber were held constant for all experiments (27 ± 0.5 °C, 20 ± 5% RH).

Exposure Conditions. The anesthetized Sprague-Dawley Rats were exposed individually to far-field 35-GHz continuous-wave RFR at an average power density of 75 mW/cm2, in E orientation (left lateral exposure, long axis of body parallel to magnetic field). This exposure resulted in a whole-body average specific absorption rate of 13 W/kg. RFR was performed until a lethal temperature was attained (The lethal event in hyperthermia due to both RFR [12] and environmental heating [13] is cessation of respiration.) Temperatures, ECG, RR, BF, and MAP were continuously monitored, and readings were recorded at 0.5 °C increments during the irradiation.

Results

Due to the fact that this experiment is in its early stages, there were many problems and complications that needed to be worked out. This caused the number of successful experimental runs to be extremely limited. In fact, only three of our many

attempts resulted in interpretable data (There were many problems in getting the flow meter to work properly). Unfortunately, three successes are not enough to analyze statistically; however, a trend was noticed in these upon which future studies will be based.

This trend involved an initial decrease in blood flow to the mesentery which we believe to occur in conjunction with the peripheral blood vessel dilation. This decrease is then followed by a steady increase until the death of the animal. The steady increase in mesenteric blood flow accompanies an almost linear decrease in blood pressure (see figure). These results are similar to those seen in a study done by Kregel, et al. (15) in which it was shown that selective loss of the compensatory vasoconstriction that normally accompanies peripheral vasodilation might be responsible for the sudden loss of blood volume that results in cardiovascular shock .

Discussion/Conclusion

These results pose the question as to what causes the pooling of the blood in the gut during peripheral heating. We have proposed

several possible mechanisms of action. One mechanism involves the activation of high-threshold cutaneous thermoreceptors (nociceptors). The type C fibers involved respond to cutaneous heating to approximately 50°C and may induce nociceptive responses (14). In 1961-62, McAfee (16,17) used microwaves to irradiate small skin areas of rats and produced substantial heating. When the cutaneous and subcutaneous temperatures reached a critical level (approx. 46°C) a nociceptive response was elicited (a dramatic decrease in MAP). If the temperature was reduced below the critical level, the depressor effect subsided. The dramatic decrease in MAP during skin heating and subsequent increase in MAP with skin cooling seen in the present study are consistent with these earlier observations.

Several other possibilities are currently being researched. These include the release of opiates from the pituitary, NO (a neurotransmitter) release, and TNF/IL-1 release from macrophages. These and other mechanisms have been shown to cause hypotension, the condition which also occurs as a response to terminal heating

What we propose is that they are all somehow triggered by the same stimulus. This is the long-term goal of present research at Armstrong Laboratory, Brooks Air Force Base, Texas.

Blood Pressure & Blood Flow vs. Subcutaneous Temperature Shifts

Left Subcutaneous Temperature (°C)

Blood Pressure (mm Hg)

Flow Rate (ml/min)

BP

flow
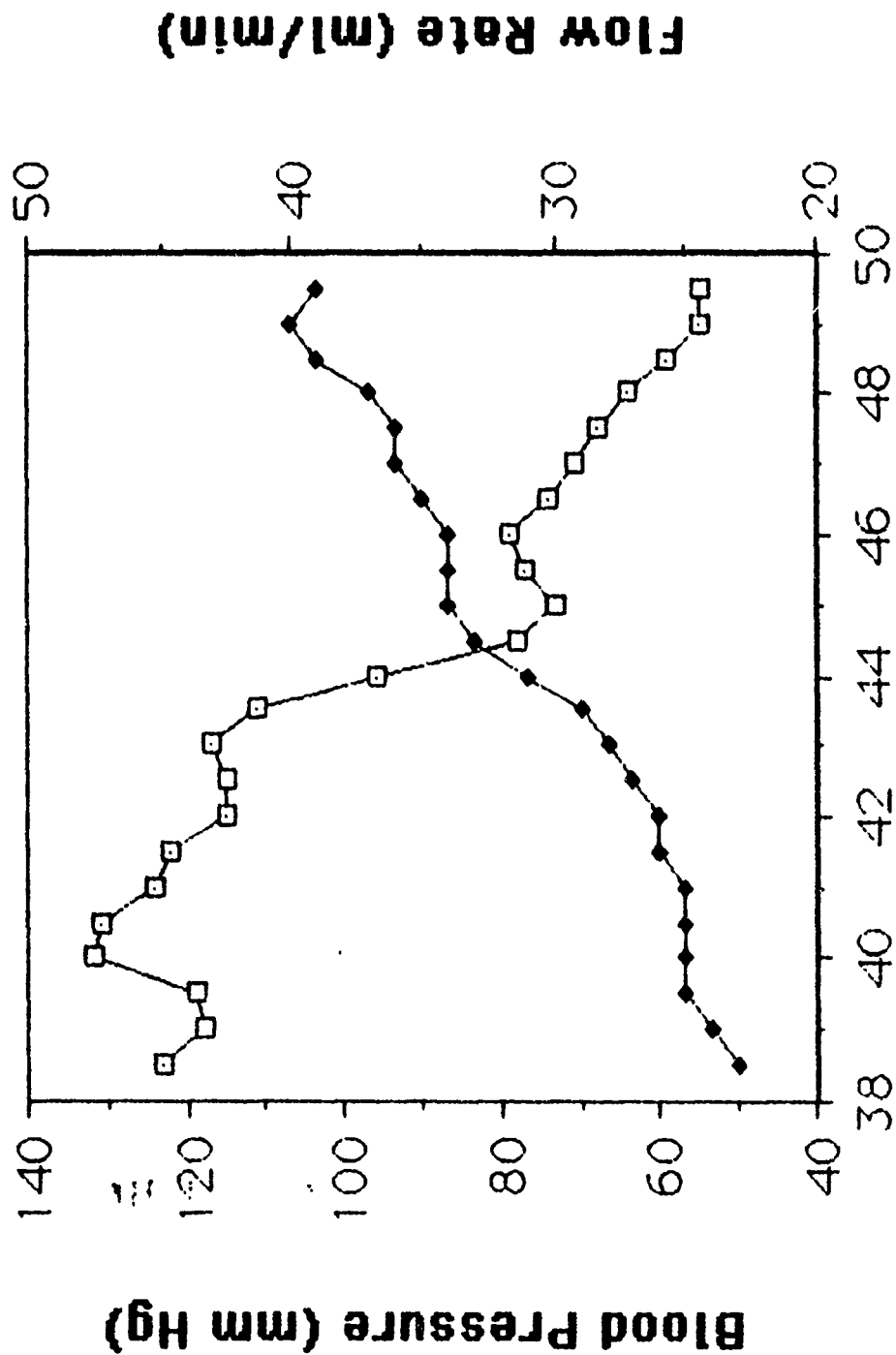
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RDL Summer Graduate Research Program

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IMAGE ANALYSIS OF RAW 264.7 MACROPHAGES POPULATIONS

Abstract

Methodologies for quantitative analysis and the visualization were studied for cell growth and foci formation in mouse RAW 264.7 macrophage cultures using Apple Macintosh computers, flat-bed scanning, light and scanning electron microscopy. Correlation between scanned optical density and seed rates was examined. Natural cubic splines were used to interpolate between physical scans in time. Methods for extracting cell counts from SEM sample images, and for visualizing possible foci statistical estimators was also examined. Other methods of visualizing culture growth were studied including three dimensional color mapped isosurface renderings of OD scan data and derivative data between scans.

Introduction

In the growing world of computational and mathematical biology, few technological and disciplinary marriages seem as natural as computational microscopy. The computer is ideally suited for the acquisition of images and the millions of discrete operations needed to transform a single image into something useful for the researcher. To the computer and the mathematician, an image is merely a two dimensional extension of a one dimensional signal. Many theorems from signal analysis extend nicely into the two dimensional realm. Within this theoretical framework is the basis for image reconstruction—coping in an

analytical fashion with "real" optical systems and the noise inherent in any quantitative system. Beyond image reconstruction is the general image transformation—applying a set of operations to transform an "ordinary" image into something more meaningful. This includes geometrical transformations for the correction of images for optical distortion, microtomy distortion, or aligning karyotypes, point operations for photometric decallibration or histogram equalization to enhance contrast and detail in digitized images, or even deblurring transformations to remove out-of-focus noise from light micrographs or to optically section a specimen. And these only represent a few possible transformations. In general however most "enhancement" transformations used to resolve a structure or image feature also lose information. What makes them meaningful is that only useful information is retained.

The volume of data generated by computational models or even microscopy can become immense. Scientific visualization—the presentation of this data in a clear and concise manner usually as an image representation—is a relatively new and promising field: all to often relegated to tomagraphic reconstruction for biology.

Discussion

The principle data gathering technique used for population densitometry studies was two dimensional scanning densitometry using a Hewlett-Packard ScanJet Plus "flat-bed" scanner. Each scanning element, or pixel, was set to be $\frac{1}{300}$th of an inch across, a horizontal scanning rate of 300 dots per inch. The pixels were assumed to be square. Additionally, the optical density resolution of each pixel was assumed to be cumulative; that

is, directly proportional to the number of cells or fractional cells lying within the boundaries of that pixel. In order to visualize the population density across the bottom of the well, a number of methods were examined including just the grey-level image returned from the scan, a pseudocolored image showing grey level changes with color gradations, or pseudocolored with bands introduced into the color look-up table or CLUT. The bands acted as contour lines, similar to those used in topographic maps. A three dimensional image could be generated under NIH Image, but this line representation was not very intuitive nor was it manipulable. It was also highly susceptible to noise in the image.

Various methods of constructing a smooth surface from a set of discrete points in three dimensions were then examined. For this, the grey level values were interpreted to represent an elevation at points (pixels) in an evenly spaced rectangular grid. These points formed our control points or nodes for the interpolation. This interpretation is commonly referred to as a "height field."

There are two basic forms of constructing a smooth surface— interpolation and approximation. Approximation produces the most smooth and "intuitive" surfaces. However, approximation does not require the surface to coincide with any of the control points. Interpolation requires the surface to pass through at least some of the control points, but this requirement can also introduce sharp discontinuities in the surface. The simplest form of interpolation is the Hermite interpolation which takes two control points and the tangents at those points to describe the surface. Bezier interpolation, closely related to Hermite interpolation, takes four control points and interpolates the two outside tangents from the two inner control points.

To describe a curve in three dimensions, the easiest and most mathematically "clean" method is to use a bicubic parametric equation of the form,

$$x(t) = a_x t^3 + b_x t^2 + c_x t + d_x$$
$$y(t) = a_y t^3 + b_y t^2 + c_y t + d_y, \qquad 0 \le t \le 1 \qquad (1.0)$$
$$z(t) = a_z t^3 + b_z t^2 + c_z t + d_z$$

This is the lowest order of interpolating polynomial which can be fitted to the initial conditions used. Higher order polynomials could be used, but are subject to an oscillatory "wiggle" that corrupts the continuity of the interpolation.

Our derivation begins by examining Hermite curves which use two control points and the tangents at those control points to interpolate a curve. These initial conditions become,

$$x(0) = P_{1x}, x(1) = P_{4x}, x'(0) = R_{1x}, x'(1) = R_{4x} \qquad (1.1)$$

Rewriting (1.0) in vector notation produces,

$$x(t) = [t^3 \, t^2 \, t \, 1] \begin{bmatrix} a \\ b \\ c \\ d \end{bmatrix}_x = T C_x \qquad (1.2)$$

The initial conditions (1.1) can be rewritten using this notation as,

$$x(0) = [0\,0\,0\,1]C_x \qquad (1.3)$$
$$x(1) = [1\,1\,1\,1]C_x$$

and by differentiating (1.2) and substituting in t,

$$x'(0) = [0\,0\,1\,0]C_x$$
$$x'(1) = [3\,2\,1\,0]C_x$$

Equations (1.3) and (1.2) can be rewritten as a system of equations,

$$\begin{bmatrix} P_1 \\ P_4 \\ R_1 \\ R_4 \end{bmatrix}_x = \begin{bmatrix} 0 & 0 & 0 & 1 \\ 1 & 1 & 1 & 1 \\ 0 & 0 & 1 & 0 \\ 3 & 2 & 1 & 0 \end{bmatrix} C_x \tag{1.4}$$

Inverting (1.4) gives

$$C_x = \begin{bmatrix} 2 & -2 & 1 & 1 \\ -3 & 3 & -2 & -1 \\ 0 & 0 & 1 & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} P_1 \\ P_4 \\ R_1 \\ R_4 \end{bmatrix} \tag{1.5}$$

$$= B_h G_{hx}$$

Where B_h is the hermitian basis matrix and G_{hx} is the associated geometry vector defined by the initial conditions (1.1). This is usually rewritten as,

$$x(t) = T B_h G_{hx} \tag{1.6}$$

with y(t) and z(t) defined by symmetry,

$$y(t) = T B_h G_{hy}$$

$$z(t) = T B_h G_{hz}$$

To derive the Bezier curve, four control points, P_1 - P_4, rather than two are used and the tangents, R_1 and R_4, interpolated from these points,

$$R_1 = P'(0) = 3(P_2 - P_1) \tag{1.7}$$

$$R_4 = P'(1) = 3(P_4 - P_3)$$

From (1.4),

$$G_{hx} = \begin{bmatrix} P_1 \\ P_4 \\ R_1 \\ R_4 \end{bmatrix}_x = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 \\ -3 & 3 & 0 & 0 \\ 0 & 0 & -3 & 3 \end{bmatrix} \begin{bmatrix} P_1 \\ P_2 \\ P_3 \\ P_4 \end{bmatrix}_x = B_{hb} G_b \tag{1.8}$$

And substituting (1.8) into (1.6),

$$x(t) = TB_hB_{hb}G_{bx} \tag{1.9}$$

Multiplying out B_h and B_{hb} and calling this B_b, produces

$$x(t) = TB_bG_{bx} \tag{1.10}$$

$$B_b = \begin{bmatrix} -1 & 3 & -3 & 1 \\ 3 & -6 & 3 & 0 \\ -3 & -3 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{bmatrix} \tag{1.11}$$

with $y(t)$ and $z(t)$ again defined by symmetry.

To extend the interpolation to surfaces in three-space, we examine parametric bicubic equations defined in two variables s and t. Reparametrizing (1.0) produces

$$
\begin{aligned}
x(s,t) = \; & a_{11}s^3t^3 \; + \; a_{12}s^3t^2 \; + \; a_{13}s^3t \; + \; a_{14}s^3 \; + \\
& a_{21}s^2t^3 \; + \; a_{22}s^2t^2 \; + \; a_{23}s^2t a_{24}s^2 \; + \\
& a_{31}st^3 \; + \; a_{32}st^2 \; + \; a_{33}st \; + \; a_{34}s \; + \\
& a_{41}t^3 \; + \; a_{42}t^2 \; + \; a_{43}t \; + \; a_{44}
\end{aligned}
\tag{1.12}
$$

or in matrix notation,

$$x(s,t) = SC_xT^T \tag{1.13}$$

Equation (1.10) can now be rewritten in the form of (1.13),

$$x(s) = SB_hG_{bx}$$

We now let G_{bx} vary with t rather than be a constant and get

$$x(s,t) = SB_bG_bx(t) = SB_b \begin{bmatrix} P_1(t) \\ P_2(t) \\ P_3(t) \\ P_4(t) \end{bmatrix}_x \tag{1.14}$$

Now let the P's be defined as,

$$P_{1x}(t) = TB_b \begin{bmatrix} q_{11} \\ q_{12} \\ q_{13} \\ q_{14} \end{bmatrix}_x \tag{1.15}$$

$$P_{4x}(t) = TB_b \begin{bmatrix} q_{41} \\ q_{42} \\ q_{43} \\ q_{44} \end{bmatrix}_x$$

Thus

$$[P_1(t)\ P_2(t)\ P_3(t)\ P_4(t)]_x = TB_bR_x \tag{1.16}$$

where R_x is the matrix formed by combining q's in (1.15). Taking the transpose,

$$\begin{bmatrix} P_1(t) \\ P_2(t) \\ P_3(t) \\ P_4(t) \end{bmatrix}_x = Q_xB_b^TT^T \tag{1.17}$$

Substituting back into (1.14),

$$x(s,t) = SB_bQ_xB_b^TT^T \tag{1.18}$$

and by symmetry,

$$y(s,t) = SB_b Q_y B_b^T T^T$$
$$z(s,t) = SB_b Q_z B_b^T T^T$$

Using this method of interpolation, a smooth three dimensional patch defined by sixteen control points, a 4x4 grid, can be constructed. Even larger smooth surfaces by generating a set of piecewise continuous patches. With Bezier patches, simply let each patch share the bordering control points. One nice property of Bezier and Hermite patches is that their control points defined a "convex control hull" which is the maximum volume of space that the curve can occupy, simplifying the integration of these three dimensional curves into existing models.

In order to transfer this mathematical model into a tangible visual representation, MacRenderMan, a very sophisticated and flexible device independent modeling/rendering system designed by Pixar™ was used. With RenderMan, any modeler or program can generate a three dimensional scene by generating ASCII or binary RIB files which describe the positioning of the scene, the objects in it, their attributes, and their relationships to the virtual world. These RIB files are then fed into the renderer which produces a picture of the scene. These RIB files are machine independent—they may be generated on a Macintosh and Rendered on a Sun Workstation, or Cray, or vice versa.

RenderMan has built-in support for height fields and piecewise continuous patches using Hermite and Bezier interpolation and, in addition, it supports B-Spline and Catmull-Rom curves. RenderMan also supports color mapping and color map interpolation between control points. With this, we were able to apply a color map such as the one based on the

black-body radiation spectrum and let RenderMan interpolate smooth color shifts between different points and correlate the colors elevation. Using a color map, another independent variable could be added to the visualization. For example, the color map can represent growth rates over time showing at a glance what the population density is and where it will be changing and how fast it will changing.

Several visualization related problems were encountered. Staring at a bumpy curve resting on a black field is not entirely intuitive. We examined adding wire frames showing the bounds of the sample domain, letting the height field be space filling, and adding a translucent box bounding the sample domain and range. The box was found to be the better technique. This gave a known volume that could be used to correlate curves between different samples and to provide an orientation for the rendering. The addition of a CLUT color bar with density markings also helped to correlate colors to quantitative values. More quantitative information could and should be introduced such as text indicating the degree of rotation and scaling, or a vector representation showing the coordinate vectors with their lengths corresponding to the scale of the image.

When scans are made over time, it is typically not feasible or at best difficult to incubate a slide on the scanning device Constantly moving the slide from the incubator to the scanner also introuuces stress on the culture. Rather than try either method, a compromise of moderately frequent scanning and interpolation of the intervening data sets was used. Each pixel of the scans was assumed to be independent of its neighbors. With this assumption, each pixel can be extracted with the grey-level value representing the dependent variable and the scan time the independent variable. One of the most popular methods of interpolation is the cubic

spline which is analogous to warping a "spline" rod so that it coincides with the sample or control points but produces a smoothly piecewise continuous curve that interpolates an unknown function between the control points. There are also two forms of the cubic spline—natural and clamped—akin to Bezier and Hermite patches. The clamped spline requires the tangents at the end points of the interpolant and fits the spline accordingly; whereas, the natural spline interpolates the peripheral tangents from internal control points.

To interpolate a two dimensional scan, a series of scans were acquired at even intervals of time, typically six hours. Every pixel in the first scan was extracted as were the corresponding pixels in the subsequent scans. A cubic spline was constructed between these grey-level values and the higher sample rate "reconstructed" by computing the grey-level values of that pixel at the new sample time.

Using this method, an approximation of the culture growth at sufficiently small intervals such as one hour, all derived from a six hour sampling rate was achieved. These images could then be rendered in three dimensions and combined to make a movie showing smooth culture growth over time.

To visualize growth rates, two methods were used, each involving static images. However, the same techniques could easily be applied to animations of growth. A simple first derivative was calculated from two scans by taking the difference and dividing by the sample rate. A second and more accurate approximation was made using a five-point approximation formula (LU). The resulting derivatives were then scaled to fill the CLUT range (0-255) and used as an index into the CLUT with higher values getting "warmer" colors. These color maps were then interpolated

across the surface using MacRenderMan. The resulting image showed the population density as well as the rates of change for each region. See Figure 1.

In order to analyze SEM images of cells for foci and population density studies, it is necessary to extract the boundaries between cells and yet discriminate between individual cells and clustered cells. The first step was to shoot a Polaroid from the SEM which was then digitized on a flat-bed scanner. Laplacian and Sobel operations were used under Enhance 1.0.1. These operations are actually discrete kernal based convolutions in two dimensions. Convolution is typically used in linear systems theory for modeling the distortion of a signal by a "response" function—noise, optical diffraction, etc... The continuous two dimensional convolution is an extension of the familiar one dimensional convolution integral,

$$h(x,y) = f * g = \int\limits_{-\infty}^{\infty} \int\limits_{-\infty}^{\infty} f(u,v)g(x-u,y-v)) \, du \, dv \qquad (2.0)$$

Digital convolution is the discrete case of (2.0) with the integrals replaced by summations,

$$H(i,j) = F * G = \sum_{m} \sum_{n} F(m,n)G(i-m,j-n) \qquad (2.1)$$

Using convolution with Laplacian kernals, such as the 5x5 kernal included with NIH Image,

$$\begin{bmatrix} -1 & -1 & -1 & -1 & -1 \\ -1 & -1 & -1 & -1 & -1 \\ -1 & -1 & 24 & -1 & -1 \\ -1 & -1 & -1 & -1 & -1 \\ -1 & -1 & -1 & -1 & -1 \end{bmatrix} \qquad (2.2)$$

approximate a nondirectional first derivative at the center point, analogous to a two dimensional form of the five-point derivative approximation given earlier. The Laplacian operator is not just sensitive to lines, however, but any change in the grey-scale of the image. This tends to enhance the noise content as well as small points rather than lines. For this reason, a Sobel operation was used. The Sobel operator is similar in that it calculates directional derivatives at each point. The resulting image can be either the magnitude of the surface gradient (averaged, largest, etc...) or the direction of the gradient at the point. The Sobel operator is far more selective towards lines than points and as such it will resolve cell boundaries nicely without emphasizing the noise content. It was also found that using the "Heavy Sobel" under Enhance 1.0.1, clusters of cells were often resolved as one large boundary.

Once the boundaries were extracted, the image was ported into NIH Image and thresholded at a 50% grey-level value. That is, all grey level values below 128, 50% of 256; we set to black and all values above 128 were set to white. This produced a binary image that is now able to be processed using NIH Image's analytical tools. The raw binary image is not an ideal image to try to analyze however. Often jagged edges, gaps, incomplete line segments, and noise are left in the thresholded image. Typically, two iterations of a morphological operation called "closing" which performs a dilation operation followed by an erosion operation were used to clean the binary image. Then the image was "outlined" creating a set of one-pixel

wide boundaries for the cells. The options for particle analysis were set to record area, x and y centers of gravity, and perimeter length. Additionally, objects touching the edges of the image were set to be excluded, and interior holes included. This last options means that the largest possible area is returned. The image was then run through the automated particle analysis feature of NIH Image and the data exported to a text file for importation into a number of statistical packages.

One method for visualizing this data is to create a three dimensional plot relating each object to its area. This was done in JMP from the SAS Institute. The X and Y Centers of Gravity were used to define the x,y location of each point which correspond to the center of each cell or cell cluster. Then the z location was defined by the area of that cell cluster. Each point could also be color-coded by perimeter length.

Another analytical technique that was used was a "circularity" estimator. Given an area, A, and perimeter, P, for a cell or cell cluster, the perimeter for an "ideal" circle was calculated, P* by,

$$r = \sqrt{\frac{A}{\pi}}$$

$$P^* = 2\sqrt{A\pi}$$

The square of the difference, $(P-P^*)^2$ was used as the estimator. The closer to zero the estimator is, the closer the object's boundary is to a true circle.

$$c^* = (P-P^*)^2 = P^2 - 4P\sqrt{A\pi} + 4A \tag{3.0}$$

Tests using blood smears identified agglutinated red blood cells as well as lymphocytes. There was some correlation between foci and large values of c* as would be expected considering the irregularity of the foci boundary. See Figure 2.

Both the area and circularity data could be combined with the x,y data and rendered using RenderMan to produce colored three dimensional surfaces representing the data.

Conclusion

The visualization methodologies are sound and significantly enhance the ability for the researcher to see changes and patterns in culture growth. There are drawbacks, however, to the gathering of the data, primarily of *in situ* cell cultures from distortion introduced by the wells and media. This may be reduced by using an inverted microscope to collect sample images from the bottom of the well and approximating the entire well bottom or by imaging the entire well bottom. It is also possible that a transmission flat-bed scanner with a higher resolution may improve the dataset. Another possible solution is to model the distortion by the well slide and attempt to decallibrate the data.

Once collected, this data can be used in optimization algorithms to locate local and global extrema and to characterize these to show quantitative data on the culture's growth patterns and possible foci development.

The SEM methodologies are also sound but suffer in their ability to discriminate between different forms of clumping. It is possible that the estimators used may be easily "fooled" if the data they are presented has not

been carefully prepared. There are a variety of other estimators that have yet to be explored, however—Hough transforms to analyze line renditions of cells, Fourier analysis, textural analysis, and the most promising, fractal analysis of the boundaries of foci.

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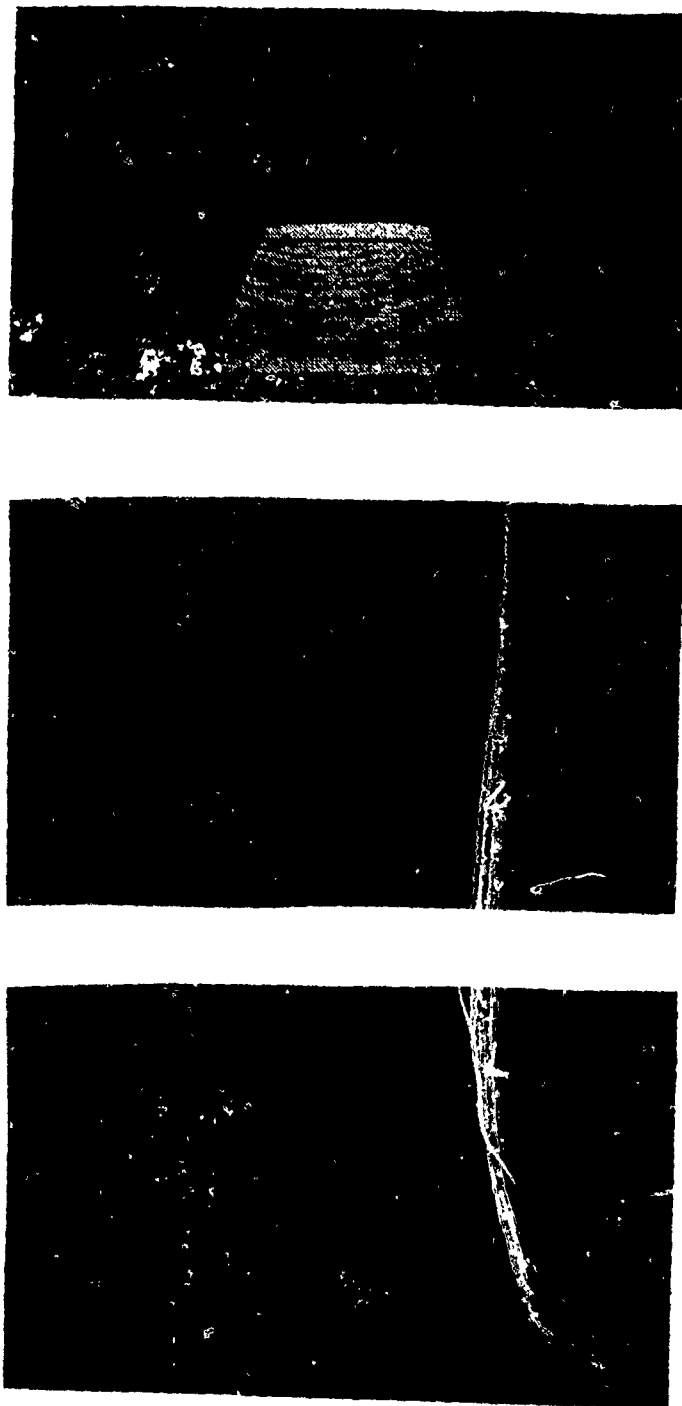
Figure 1.
These three photographs represent the relative growth of RAW cells on the surface of their culture chamber. The top photo represents one day of growth. The middle photo represents three days growth and the bottom photo represents five days growth.

Components

X	X Center
Y	Y Center
Z	c*
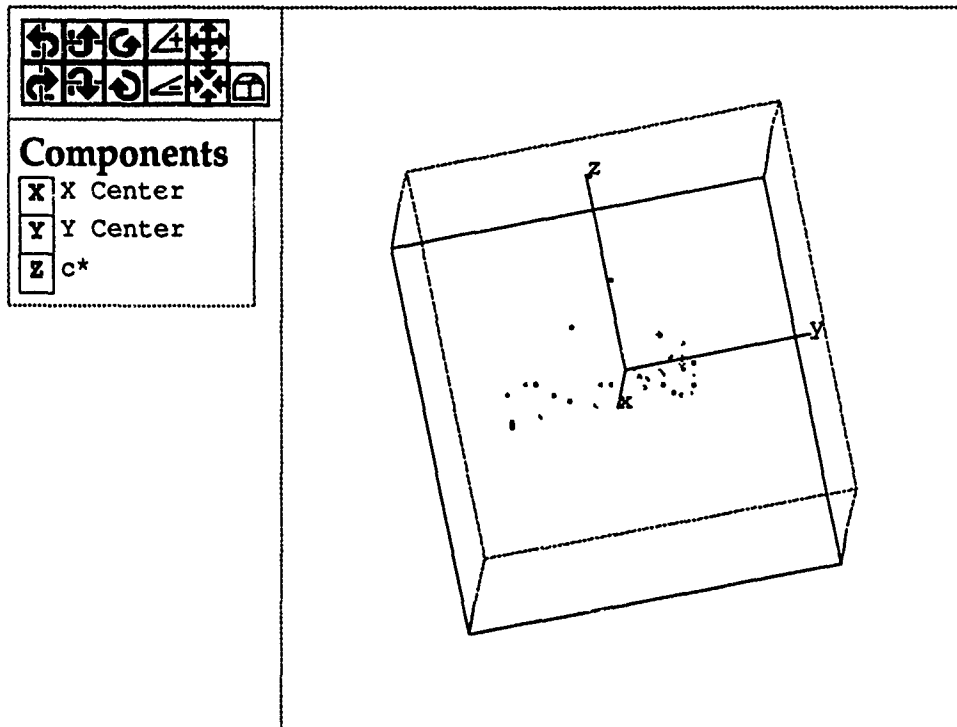
Figure 2-1

(RAW W 2, color per 200 p^2)

This figure shows a graph of cells extracted from an SEM of RAW cells. The X and Y axis are the X and Y locations of each cell or cell cluster with the Z axis representing the degree of non-circularity. Each point is also color coded so that blues represent cells with the smallest area and reds the highest—a color change for every 200 square pixels.
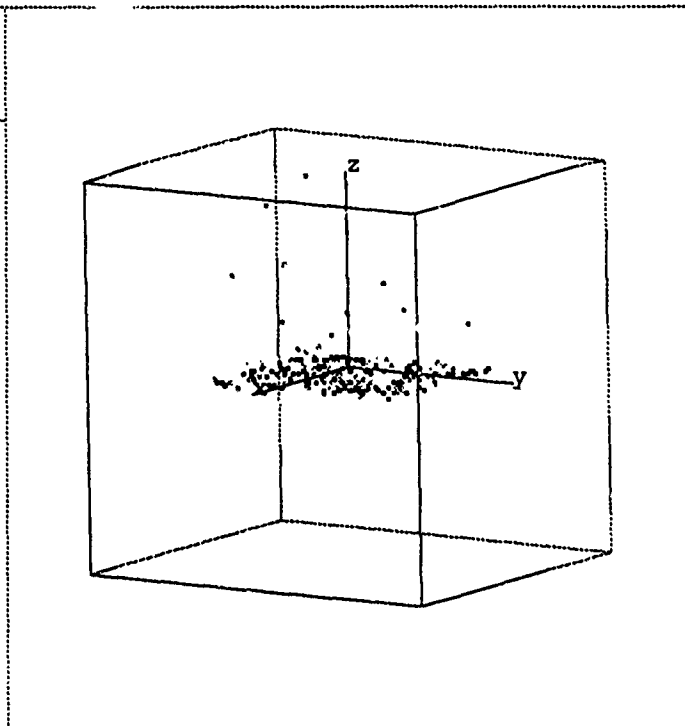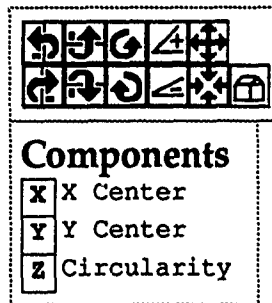
Figure 2-2

(RAW W4, color per 200 p^2)

This figure uses the same technique as Figure 2-1 except that it is of a different well.

Note the distribution of high elevation red dots indicating likely foci.

MODELLING HUMAN PERFORMANCE DURING SUSTAINED OPERATIONS

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ABSTRACT

Requiring people to make unusual shift changes or work for extended periods of time results in a disruption of natural bodily rhythms, and subsequently, their performance is degraded. A model which predicts performance degradations following the disruption of natural bodily rhythms would be useful as a decision making and staffing aid. Thus, two statistical models were developed to predict different facets of human performance during sustained operations: a reaction time model and an accuracy model. Both models utilize hours awake and melatonin levels as predictor variables. The predictor variables accounted for 33% the variance in reaction time performance and 18% of the variance in accuracy performance. Implications and future directions are discussed.

ACKNOWLEDGEMENTS

INTRODUCTION

A helicopter on an SAR (search and rescue) mission crashes into the ocean while flying at night in rain showers; causal factor--pilot error compounded with possible vertigo and disorientation. Post mishap investigation revealed that although the pilot had slept 27.5 hours in the past 4 days, only 4.5 had been within 24 hours of the crash and that had been from 6:45 a.m. to 11:15 a.m. (Borowsky & Wall, 1983, p. 535).

Aerospace transportation exposes travelers to environmental signals that are shifted in time. Such exposure may result in the alteration of circadian rhythms which is referred to as circadian desynchronosis. The desynchronized individual may experience a variety of symptoms including: irritability, disorientation or confusion, distortion of time and distance, aches of various types, digestive upsets, decrements of physical and mental efficiency, and disturbances in sleep habits. The potential safety hazards of sleepiness and fatigue induced by circadian desynchrony and sleep disturbances may be of serious consequence among airline pilots, astronauts, cosmonauts, and their supporting crews (Vignet et al., 1984).

According to astronaut's subjective reports, sleep disruption is a common occurrence on Shuttle missions with many crewmembers sleeping fewer than five hours on some nights, and less than two hours on others (Santy, Kapanka, Davis & Stewart, 1988). Furthermore, fatigue has been shown to negatively impact both mental and physical performance in spacecrew (Christensen & Talbot, 1986; Santy, Kapanka, Davis & Stewart. 1988).

Aircrew members are also affected by fatigue. In fact, fatigue and circadian disrhythmia have been implicated as causal factors in a number of aircraft mishaps (NTSB, 1987). For example, Borowsky and Wall (1983) reviewed the data gathered from 1978-1983 pertaining to U. S. naval pilot involved in class A flight/flight related (F/FR) mishaps (i.e., those involving intent for flight with destroyed aircraft, fatalities, permanent total disabilities or at least $500,000 of property damage and injury costs). They found that fatigue/sleep deprivation was a definite or suspected factor in nearly 70 naval aviation class A F/FR mishaps during this five year period. Further, Ribak and associates (1983) reviewed an Air Force accident data base covering twelve years (1968-1980). They were interested in the Hourly Accident Coefficient (HAC), or the frequency of accidents for each hour, h_i, divided by the frequency of flights for that hour, h_i. The researchers noted that the HAC pattern exhibited a diurnal rhythm which was independent of the frequency of flights and appeared to be related to the sleep-wake cycle of the pilots. In particular, the investigators discovered that higher HAC levels were associated with the hours immediately following the pilot's waking from his/her night sleep.

In addition to such historical data, the negative effects of desynchronosis and sleep disruption have been demonstrated in operational settings. Specifically, Beh and McLaughlin (1991) examined performance levels of flight attendants following layover periods on both eastward and westward long-haul flights. They found that the mental performance of the attendants was adversely affected when flight scheduling and duty rosters resulted in

considerable disruption of normal sleep routines. Similar performance degradations have been observed following experimentally induced disrhythmia as well. For example, ground-based phase shift studies have used cockpit simulators to simulate eastward and westward flight (e.g., Klein et al '976). As has been observed in operational environments, phase ~nces, induced through simulated eastward flight, resulted in greater performance decrements than phase delays which were induced through simulated westward flights.

Given the performance decrements observed following circadian desynchronosis and sleep disruption or fatigue, one would speculate that much attention would be paid to developing predictive equations which could be used to predict performance following these disrupters. Winget and associates (1984) reviewed the literature pertaining to performance changes associated with desynchronosis. In particular, they discussed the importance of mathematical models of desynchronosis, and they present three general classes of models. One class of models has been developed to calculate appropriate rest periods following transmeridian flight (Buley, 1970; Gerathewohl, 1974; Mohler, 1976) and workload where workload is defined as the product of days on duty and average duty hours per day (Nicholson, 1972). A second class of models has been developed to quantify the dynamics of the rephasal process (e.g., Winget et al., 1975 in Winget et al., 1984). A final class of models utilizes a stable oscillator underlying body temperature circadian rhythms and a labile oscillator underlying the sleep/wake cycle to

provide a basis for predicting sleep onset and duration (e.g., Czeisler et al., 1980).

The models which currently exist in the literature offer a means to predict appropriate rest periods, workload level, sleep onset, and sleep duration. However, no model could be found in literature which predicts degradations in performance following sleep disruption or the onset of fatigue. A model which could predict performance decrements during sustained operations would be useful as a decision-making aid. Specifically, this type of model could be used to estimate when an aircrew member has reached a fatigue level associated with poor performance. In addition, the model could be used to efficiently use available personnel. For example, in a monitoring task such as radar screen monitoring minimal crewmembers would have to be assigned to monitor the necessary equipment when the model predicts high performance. However, additional crew members could be assigned to the consoles during periods when the model predicts poor performance due to sleep disruption or fatigue. Thus, continued adequate performance levels would be insured.

In addition to serving as a decision-making and staffing aid, an equation predicting performance decrements due to sleep disruption or fatigue could be integrated into a simulation of human performance on a generic task during sustained operations. Specifically, a MicroSAINT model of a generic sustained task could be developed for demonstration purposes with the predictive equation included at the appropriate nodes to demonstrate degradations in performance following fatigue. For example, Figure 1 illustrates a

flow diagram of the serial addition-subtraction test of the Walter Reed Performance Assessment Battery (WRPAB, Throne, Gensen, Sing, & Hegge, 1985; Perez, Masline, Ramsey, & Urban, 1987). Once this test was modeled as a MicroSAINT task, a predictive equation could be included at the appropriate nodes to allow the user to compare serial addition-subtraction performance under different time and physiological conditions by manipulating the predictive equation parameters. Given the benefits of developing a predictive model of fatigue, the current project was undertaken.

Insert Figure 1 about here

The performance scores and physiological measures of subjects from French, Hannon and Brainard (1990) were used to develop the predictive equations. In this 1990 study, the investigators examined the effects of bright illumination on sustained performance by comparing performance during 30 hours of exposure to bright light or dim light. The dim light condition was intended to represent fatigued performance uninfluenced by lighting. Thus, only data from the dim light condition was used in the current paper for equation development. A brief description of the methodology used in the French, Hannon and Brainard (1990) study follows.

METHOD

Subjects

The subjects were ten males in their early to mid-twenties. Males were used to simplify the neuroendocrine assays. They were recruited from non-smoking civilian and military personnel at

Brooks Air Force Base. Subjects were required to abstain from all drugs and prolonged sunlight for 24 hours prior to arriving for the experiment. In addition, they were to have a normal night of sleep prior to each test period. Five subjects were tested at a time. All subjects signed consent forms to participate. One subject was unable to complete the study.

Materials and Procedure

All subjects participated in two 30 hour test sessions: one bright light (3000 lux) session and one dim light (100 lux) session. Two weeks separated the sessions to allow re-entrainment of circadian rhythms and recovery from sleep loss. The order in which the sessions were attended was counter-balanced. Subjects were tested in individual, sound attenuated work stations. A light source fixture which could be adjusted to produce either bright or dim light was suspended above each booth (Vita-lite, Duro-test Corp., NJ). Within each booth, the subject sat at a PC work station.

The subjects arrived at each session at 0700 hours to be familiarized with the test battery before testing began. The first three test trials occurred under dim illumination at 1000, 1400 and 1600 hours in order to stabilize performance. From 1800 hours (Day 1) to 0600 hours (Day 2), seven treatment trials under either bright or dim light took place every two hours. The trials consisted of a cognitive test battery followed immediately by physiological measurements. To assess the duration of any illumination effects following the return to dim illumination, subjects performed under the dim illumination condition from 0600 to 1200 of day two. Subjects were required to stay in their booths throughout the study

with the exception of short (<5 minute) restroom breaks. Social interactions were kept to a minimum. The same foods were served at the same time to the subjects in their booths during both light conditions.

Each trial consisted of a cognitive test battery followed immediately by physiological measurements. The order that the tests were presented did not vary throughout the study. Five performance subtasks were taken from the Walter Reed Performance Assessment Battery (WRPAB, Throne, Gensen, Sing, & Hegge, 1985; Perez, Masline, Ramsey, & Urban, 1987). They included choice reaction time, column addition and subtraction, the manikin test, serial addition and subtraction and Wilkinson reaction time. Subtasks were also obtained from the Complex Cognitive Assessment Battery (CCAB, Hartel, 1988; Perez et al., 1987) including the tower puzzle, following directions, the numbers and words dual process task, and route planning. Two subjective measures were also used: the Profile of Mood Survey (POMS) and the Stanford Sleepiness Scale (Perez et al., 1987). Physiological measures included oral temperature, eyeblink frequency, and neuroendocrine (i.e., plasma melatonin, cortisol and testosterone) levels.

RESULTS AND DISCUSSION

Overview of Analysis

Two types of performance variables were modeled in this effort: reaction time variables and accuracy variables. Performance scores such as the percent missed scores of the numbers task from the CCAB were considered accuracy variables, while performance

scores such as the task duration scores of the serial math task from the WRPAB were considered reaction time variables.

Reaction time and accuracy variables which were sensitive to fatigue were included in the effort. Subtests were considered sensitive to fatigue if performance degraded from baseline levels over time. After the reaction time and accuracy variables were chosen, the scores were normalized using the following formula: (score at $hours_i$ / score at $hours_{1800}$) * 100. That is, the scores for each hour were divided by the score observed at 1800 hours. This value was then multiplied by 100. Thus, performance was analyzed based on percent change from baseline, with baseline being performance at 1800 hours or at the twelve hours awake test sample.

Multiple regression was used to determine the percent of performance variance accounted for by the predictor variables. Two predictor variables were chosen: hours awake and plasma melatonin levels. These predictors were chosen because performance degradation due to fatigue seems to consist of two components. First, performance degrades linearly over time. Hours awake was chosen to represent this linear component. Second, within the linear performance degradation, there appears to be a cyclical component, with performance cycling up and down in a somewhat rhythmic manner. Plasma levels of the hormone melatonin were chosen to represent this rhythmic component, since melatonin secretion follows a circadian rhythm in human subjects, and high levels of melatonin have been associated with decreased self-reported alertness, increased confusion and slowed reaction times (Lieberman et al.,

1984; 1985). Thus, the melatonin component of the equation would account for oscillating performance. In addition, the melatonin component would capture degradation due to "subjective night." Figure 2 depicts the average plasma melatonin levels over a 24 hour period for the nine subjects in the French et al. (1990) study.

Insert Figure 2 about here

Reaction Time Variables Modeled

Two reaction time variables were chosen which were sensitive to fatigue. The two variables, both of which are from the serial math section of the WRPAB, were total time on task and response time for correct answers. The scores on these two variables were normalized and averaged together to create a composite reaction time score. Figure 3 illustrates the normalized average composite reaction time across hours awake. The reaction time predictive equation was developed with the composite score. Table 1 lists the means and standard deviations of the composite reaction time score across hours awake.

Insert Figure 3 about here

A multiple regression was performed with hours awake and melatonin predicting performance on the composite reaction time variable. The multiple R^2 = .33 was significant, F (2, 78) = 18.83, p = .0001. Thus, taken together, hours awake and melatonin accounted for 33% of the variance in reaction time performance. Figure 4

depicts the observed composite reaction time scores and the predicted reaction time values based on the multiple regression equation.

Insert Figure 4 about here

Tests on the regression coefficients were then conducted: B_{hrs}, $t (79) = 6.01$, $p = .0001$; B_{mel}, $t (79) = 0.35$, $p = .095$. Tests on the regression coefficients or beta weights (B) indicate the increment in performance variance independently accounted for by each variable. Thus, hours awake independently accounted for a significant increment in reaction time performance variance, while melatonin did not.

Accuracy Variables Modeled

Three accuracy variables were chosen which were sensitive to fatigue. All three of the variables are part of the CCAB. They included percent good hits on the numbers subtask, percent marked hits on the following directions subtask and percent hits on the following directions subtask. As with the reaction time variables, the scores on the accuracy variables were normalized and averaged together to create a composite accuracy score (see Figure 3). As with the reaction time equation, the accuracy predictive equation was developed with the composite score. Table 1 lists the means and standard deviations of the composite accuracy score across hours awake.

Insert Table 1 about here

A multiple regression was performed with hours awake and melatonin predicting performance on the composite accuracy variable. The multiple R^2 = .18 was significant, F (2, 78) = 8.45, p = .0005. Thus, taken together, hours awake and melatonin accounted for 18% of the variance in accuracy performance. Figure 5 depicts the observed composite accuracy scores and the predicted accuracy values based on the multiple regression equation.

Insert Figure 5 about here

Tests on the regression coefficients were then conducted: B_{hrs}, t (79) = -3.93, p = .0002; B_{mel}, t (79) = -2.17, p = .033. Thus, both hours awake and melatonin independently accounted for a significant increment in variance of accuracy performance.

The reaction time and accuracy models must be submitted to a validation process by applying them to a separate set of data. Determining if the models successfully predict performance following sleep disruption or fatigue in a separate set of data will decide if they are useful or not. Meanwhile, the equations were able to account for a significant amount of variance in the predicted performance variables of the current data. The proportion of variance accounted for should be kept in mind however. The reaction time equation accounted for 33 percent of the variance in reaction time performance, and the accuracy equation accounted for

only 18 percent of the variance in accuracy performance. While this is certainly progress, a considerable portion of the variance remains unexplained.

Research is needed to further refine the predictor variables. Hours awake contributed significantly to both the prediction of reaction time and accuracy. However, melatonin only contributed significantly to the prediction of accuracy. While both reaction time and accuracy exhibited rhythmic degradations, perhaps these fluctuations would be better predicted by a cycle other than a circadian rhythm such as melatonin.

In addition to determining which cycle best fits fatigued performance, future research should attempt to identify a variable or set of variables which distinguishes subjects who perform well during sustained operations from those who do not. Upon examination of the plots of individual subject's performance, it was noted that subjects appear to respond differently to fatigue. Some subjects exhibited degraded performance which "rebounded" for a period, and then degraded again. Other subjects demonstrated consistent performance degradations with few "rebounds." Still others showed relatively consistent performance throughout the measurement period and did not appear to be dramatically affected by sleep disruption. Such inter-individual differences in physiological, biochemical and psychological variables measured at several different times of day have been noted previously (e.g., Kerkhof,1985). Future research efforts should focus on determining a variable or set of variables which could distinguish those who are affected by fatigue from those who are less affected by it.

Future research should also examine and model the responses of female subjects to sleep disruption and fatigue. In order to generalize to all aircrew members, empirical data must be collected on females. Finally, additional data should be collected on periods longer than the 30 hours used in the French et al. (1990) study in order to determine if the predictive equation developed here could be used to reliably predict performance during periods longer than 30 hours.

	Hours Awake								
	12	14	16	18	20	22	24	26	28
Reaction Time (ms)	100.0	78.6	103.4	100.3	112.5	121.9	114.1	120.8	127.9
	(0)	(8.9)	(12.2)	(12.2)	(15.6)	(15.5)	(19.0)	(17.2)	(20.0)
Accuracy	99.95	109.6	100.0	84.5	83.6	71.6	74.7	86.0	75.7
	(.04)	(2.9)	(6.2)	(8.1)	(12.8)	(11.3)	(9.7)	(9.4)	(10.4)

Note: Standard deviations are in parentheses.

Table 1.   Means and standard deviations for the composite reaction time and accuracy scores across hours awake.

Figure 1. A MicroSAINT model of the serial addition-subtraction test of the UTC-PAB.
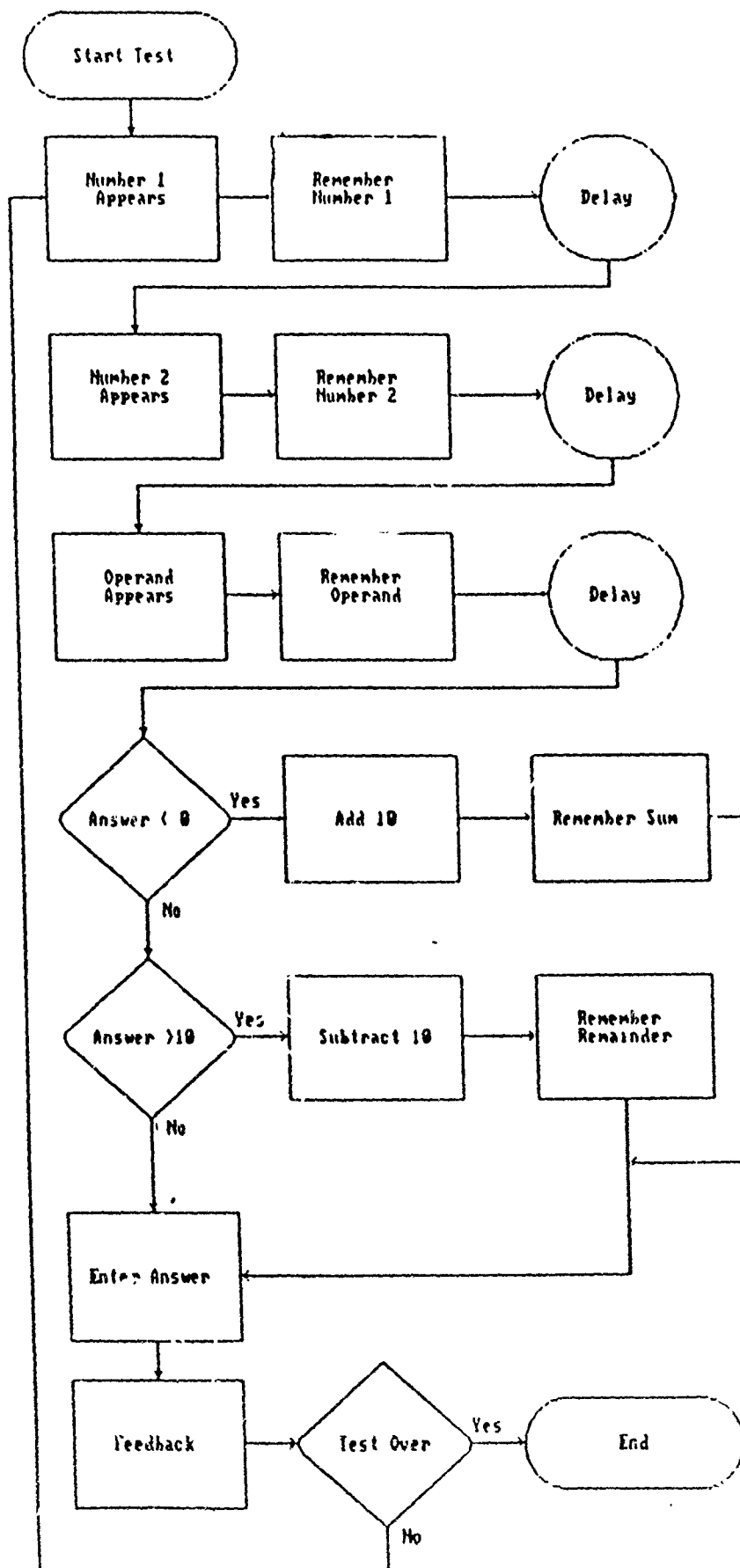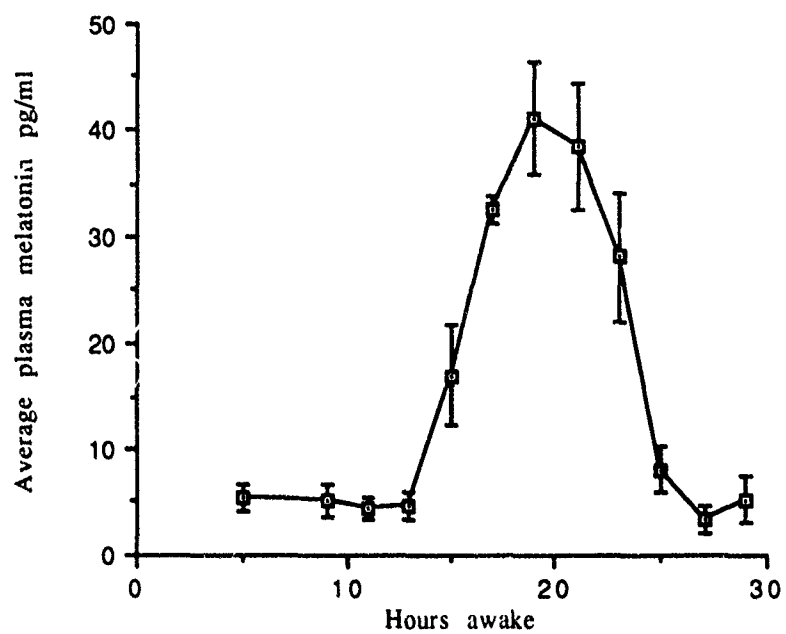
Figure 2. Average plasma melatonin levels for nine subjects over a 24 hour period.
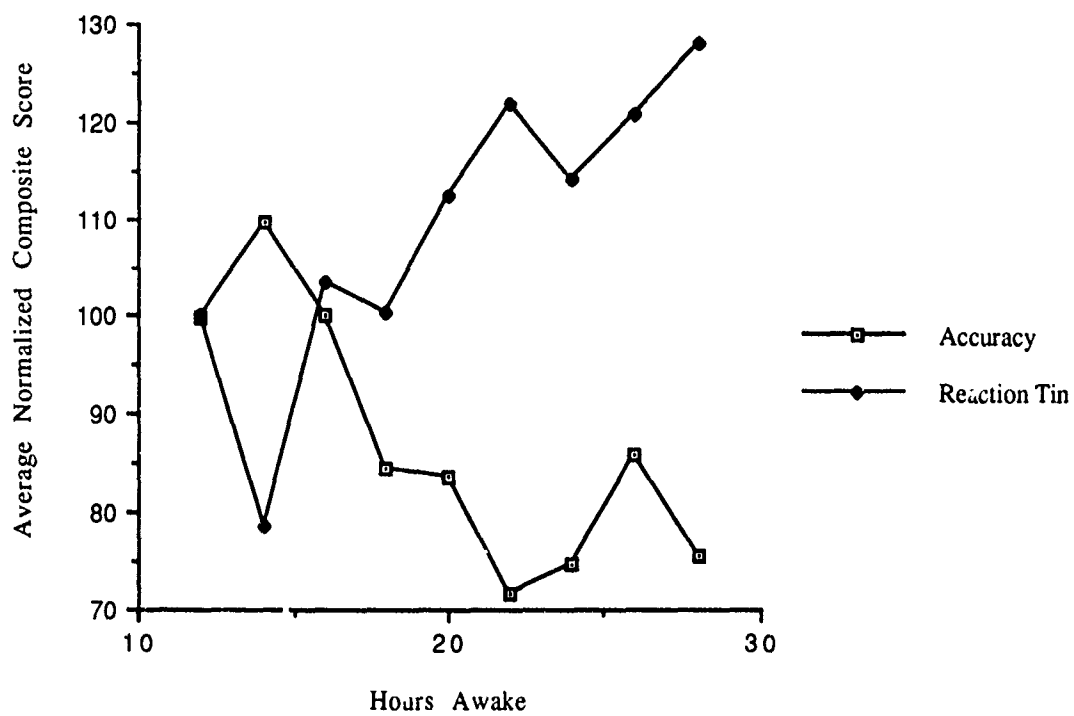
Figure 3. Average normalized composite reaction time and accuracy scores across hours awake.
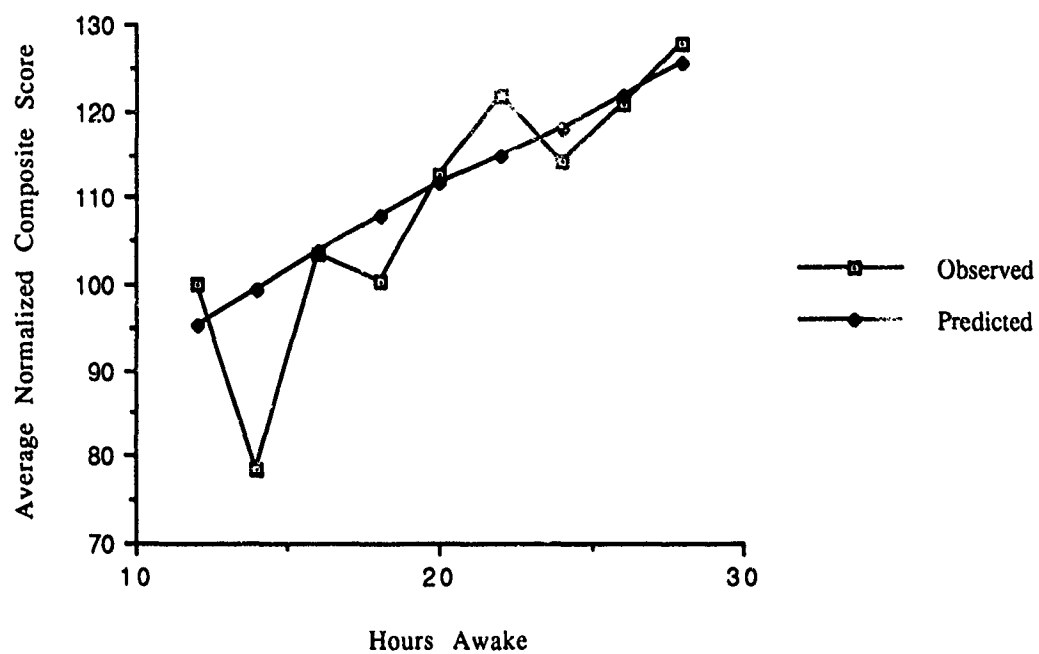
Figure 4. Observed and predicted reaction time scores.
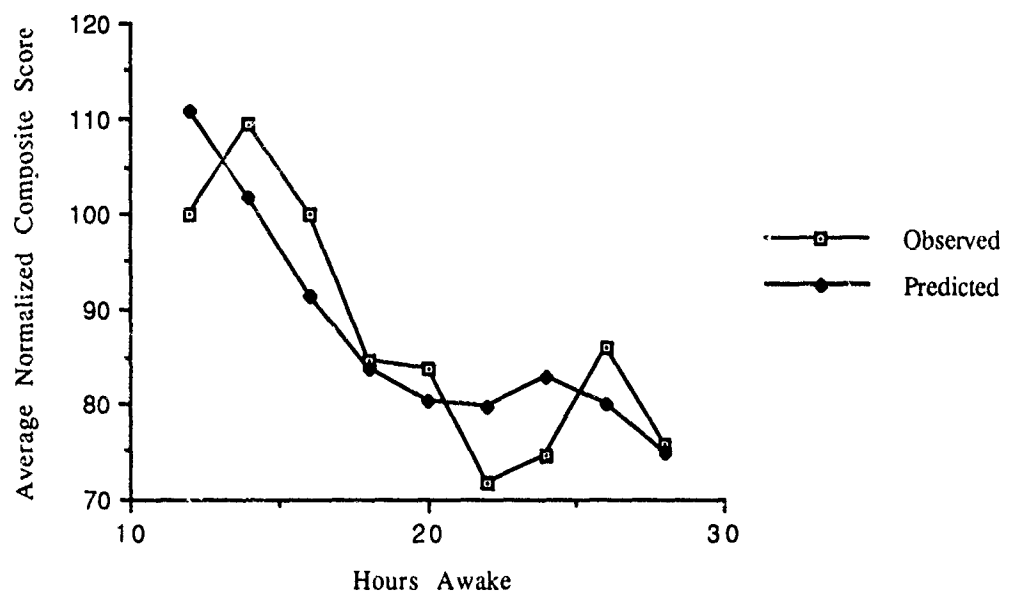
Figure 5. Observed and predicted accuracy scores.

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USE OF THE CARBOCYANINE DYE DiI FOR CORRELATION OF ANATOMICAL AND FUNCTIONAL PARAMETERS IN TWO EXPERIMENTS INVOLVING X-RAY INDUCED HYPOPLASIA

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ABSTRACT

The purpose of the study was to complement and expand on
two ongoing experiments involving neural grafts and the
NMDA agonist, MK 801 and their association with x-ray
induced hippocampal granule cell hypoplasia[1,2]. The
primary goal being to investigate and develop the use of
carbocyanine dyes, DiI and DiO, for labeling of neurones
in fixed rat tissue obtained from the experiments
mentioned. Specifically, the growth and arborization of
neurons was analyzed and explored with the use of the
neuronal marker. A technique was developed for the
application of the dye, post injection clearing of the
tissue, and for the viewing and photographing of the
stained tissue. Preliminary results are positive and
indicative of the various factors affecting DiI staining
of fixed tissue, e.g., amount of dye needed and time
required for diffusion. Using fixed tissue produced
similar results to those observed when fresh tissue was
used, but it required considerably more time for the dye
to diffuse through the tissue. At the present rate of
diffusion, final results will not be available for one to
two months.

INTRODUCTION

Two experiments involving x-ray induced hypoplasia were

extended during the course of this study. The first experiment

consisted of studies evaluating the survival and neural

connectivity of neural grafts in normal and damaged hippocampal

tissue[3]. According to Mickley et al,[1] the ability of neural grafts

to affect behavior of radiation induced hypoplasia of granule cells

in the fascia dentata is dependent on the source and ultimate

location of the donor neural tissue. Moreover, it was shown that

grafts of fascia dentata granule cells residing in an appropriate

area reduced behavioral dysfunctions caused by radiation induced hypoplasia. The functional connectivity of neural grafts was visualized by Senseman et al[3] using optical recording techniques and those results substantiated the view that homologous grafts were more likely to form functional connections with surrounding host neurons than non-homologous grafts. The use of a neuronal tracer to visualize possible graft/host interconnections was one goal of the present study.

The second experiment studied the effects of MK-801, an NMDA antagonist, on behavioral deficits also associated with x-ray induced hippocampal damage. Since it has been shown that MK-801 helps to protect newborns from brain damage evoked by hypoxia, this study wanted to test if MK-801 could alleviate or reduce behavioral deficits due to irradiation of the hippocampus[2]. Results have shown that MK-801 facilitated the learning of the water maze by rats that were irradiated. Thus, the data reported by Mickley et al, strongly suggest that early treatment with MK-801 will certainly produce a dose-dependent protection to irradiated subjects. Again, the use of a neuronal marker was warranted in order to look for possible differences in neuronal arborizations in MK-801 treated subjects.

We proposed that the carbocyanine dye DiI would serve well in correlating the functional and anatomical parameters of these

experiments. DiI has several very promising features: DiI (1,1'-dioctadecyl-3,3,3',3' tetramethylindocarbocyanine perchlorate) is a lipid soluble fluorescent dye and one of several in the carbocyanine family. They are all composed of the same basic structure with variations only at the y position (see Fig. 1). Variations of this structure give rise to DiI, DiO, and DiS with isopropyl, oxygen, and sulfur groups at the y position respectively. Although these dyes have been widely used in other areas of biology, it was not until 1985 that Honiq and Hume[4] found that they provided excellent staining of the central nervous system.

They proceeded to demonstrate their primary advantages including the ability to stain very intensely and their relative non-toxicity. As compared to horseradish peroxidase (HRP), they found that DiI also worked well with living tissue proving indispensable in neuroscience research. It was also seen than in contrast with other conventional tracers such as lucifer yellow, DiI did not fade rapidly and had the ability to be used in combination with other markers. The dyes not only remained in the cells for long periods of time, but there was virtually no leakage to other cells especially in fixed tissue[5]. It was those finding that supported the view that the dyes moved by lateral diffusion in fixed tissue while due to axonal transport in the living tissue.

The actual technique for the use of the dye was developed in our lab following methods in the literature[4,5]. The procedure was rather simple requiring injection of the dye crystals directly on the chosen site under a dissecting microscope. After a simple clearing procedure with increasing concentrations of glycerol, the tissue was viewed under fluorescence. Preliminary results have provided images of neuronal pathways and have shown spread away from the site of injection. Also, we did not see spread to other cells that were not in the injected neuronal pathways.

EXPERIMENTAL PROCEDURES

Fresh tissue

Brains were cut in coronal sections at 200 and 300 um on a vibratome. Sections were placed in 4% paraformaldehyde (in 0.1 M phosphate/thimersol buffer) for 1 hr at 4°C and then transferred to 2% paraformaldehyde and stored at 4°C.

Fixed tissue

<u>Neural graft experiment</u>

The rats were perfused with heparinized saline followed by buffered formalin. They were decapitated, brains sliced on a vibratome (200-400 um) and recorded from using optical recording techniques. At the end of that study, they were stored in formaldehyde (in 1.0 M phosphate buffer) for one year. Prior to

injection, the slices were treated in 4% paraformaldehyde for 1 hr and stored thereafter in 2% paraformaldehyde (1.0 M phosphate/thimersol buffer) at 4°C.

MK-801 experiment

Rats received same treatment as above but were stored for one year as whole brains. Sagittal sections (300 um) were cut on a vibratome and placed in 4% paraformaldehyde for one hour followed by 2% paraformaldehyde and stored at 4°C.

Tissue buffer

Paraformaldehyde (80 g) was added to 200 ml of 0.1 M phosphate/thimersol buffer. [Sodium phosphate dibasic (43.16 g) and 5.80 g of sodium phosphate monobasic monohydrate (0.04 M NaH_2PO_4) was added to 2000 ml of distilled water, pH 7.3-7.4. Thimersol (0.2 g) was then added.]

Clearing of tissue

The fixed tissue was cleared prior to examination under fluorescence by suspending it in increasing glycerol concentrations (20, 40, 60, 80, 95 and 100%). Tissue was kept in each concentration for 10 minutes with exception of the 100% concentration which required an overnight incubation.

Dye

The lipophilic carbanocyanine dye DiI [Molecular Probes, Eugene Oregon] was used as the tracer of choice. Few crystals were

placed on a glass slide and transferred to a fine tip micropipette by carefully rolling the latter on the slide. Inspection of the micropipette tip under the dissecting microscope was necessary in order to ensure that a sufficient amount of DiI was present without excess or clumping, however. The micropitte was placed on a manipulator [Prior, England] to guide the tip to the proper injection site on the hippocampal slice placed under the dissecting microscope [Heerhrugg Wild MS,Switzerland]. The injection area of choice in our experiments was ventral CA3 for the MK-801 rats and within the neural graft for the transplanted subjects (see Figure 2).

Storage of tissue

Tissue was stored in 2% paraformaldehyde after injection. It was kept in the dark and at room temperature. It was occasionally (about once a week) checked expediently under the microscope in order to view progress, but the sections were usually kept stored for at least four weeks before viewing for longer periods of time. Precautions were taken to avoid exposing the slices to prolonged and intense amounts of lights so as to prevent premature fading of the dye.

Analysis

Sections were analyzed and photographed under fluorescence microscopy using a Nikon Optishot microscope with a 100 watt

mercury lamp, Nikon G-1B filter block (rhodamine filter), and a Nikon HSF automatic exposure timer. Photographs (10 and 40X mag) were taken with Kodak, T-Max 400 ASA black and white film.

RESULTS

Preliminary results from "practice data" (non-essential rats used to perfect technique and functioning as controls) has generated various important observations. First of all, the DiI has provided precise images of neuronal projections, not only in fresh tissue, but also in the one-year-old tissue (see Figs. 3 & 4). There was rather uniform labeling that has remained intense even with weeks of incubation. Secondly, spread away from the site of injection has been established (see Fig. 5). The fixed tissue has stained well, but when we compared our observations to those in the literature[5], it seems as if the dye is taking longer to diffuse in fixed tissue than in living tissue. We have yet to observe any transfer from the labeled processes to other cells around them. Furthermore, viewing of cells under different focal planes yielded fluorescent images of concentric circles around stained cells demonstrating that the dye is located in the cell membrane. Although results are not yet available for the bulk of the data, labeling of granule cells in the fascia dentata in one year old fixed tissue has been achieved.

DISCUSSION

The use of a tract-tracing method was required in order to successfully complete the experiments involving neural grafts and MK-801. DiI seemed to be the perfect choice for labeling processes to verify neuronal extensions from grafts into host tissue. Also, it will be very useful in determining if MK-801 had an effect on neural projections responsible for the behavioral changes observed. Once the label diffuses through the injected tissue, correlations between arborizations and behavioral outcomes will be more feasible.

Overall, the general techniques developed for the use of the diI proved to be effective for our needs. It was found that seemingly minor details proved invaluable in improving the rather crude technique. Although there are various methods of applying the dye, including dissolving in solvents, direct injections of crystals into the tissue was better for our purposes. It has been reported that direct application works much better as minimal spread is seen when using dissolved dyes in fixed tissue[5]. A fine tip micropipette was preferred for application as it generated a precise site of injection. Also, wetting the tip of the pipette with buffer proved useful in adherence of the dye to the micropipette with less clumping. Furthermore, the diI crystals were also crushed on the slide prior to mounting to further avoid

clumping and to prevent excess uptake. Early data also showed that a minimal injection of diI was sufficient to stain the projections well and, in fact, we grew to prefer this procedure as it produced a more distinct image with less background haze when the sections were photographed.

Formaldehyde in 1.0 M phosphate/thimersol was the buffer of choice used to store the injected tissue because it has been shown to produce a marked reduction in background fluorescence[5]. Furthermore, in order to minimize any bleaching, tissue was handled and stored in the dark and at room temperature. Prior to viewing, tissue was cleared with increasing concentrations of glycerol. However, not much difference was noted between the treated and non-treated tissue. Individual slices were then placed on slides and coverslipped with particular attention in preventing the drying of the tissue. Drying not only makes it very hard to see processes, but it destroys the label as well. The slides were observed under fluorescence with a rhodamine filter as DiI is excited at a maximum in the green and fluoresces a bright red-orange (excitation 547 and emission 571). The slices were then placed back in buffer after viewing.

As seen in the results, the early photographs have shown distinct labeling of processes and spread away from the site of injection. Although there was initial skepticism over the use of

such old fixed tissue, its use may have actually contributed to better results. First, the labeling thus far has been bright and uniform as opposed to granular or clumped as it is more often seen in living tissue. Since the dye is incorporated in the plasma membrane of fixed tissue, it is much easier to visualize a distinct outline of cells. In the live tissue, there is some loss of the dye due to membrane turnover and cell function thus it may not be as bright and might appear granular.

Moreover, the dye seems to diffuse almost indefinitely with time in fixed tissue, thus allowing maximal labeling of entire processes and projections. This is virtually impossible to see in living tissue as dyes are often degraded and eliminated before the dye can diffuse completely through entire pathways[7]. Therefore, even though our fixed tissue definitely takes longer in the diffusion process, the staining remains bright and actually improves with time. Finally, crossover or leakage to other cells that were not directly on the labeled pathways has not yet been detected. This again indicates that the label is appropriately located in the plasma membrane of the cell.

In conclusion, our initial data indicate definitive labeling of cells in the hippocampus. DiI has worked well and has allowed us to perform tracing studies in fixed tissue. A very important advantage of the dye is that the tissue can be kept as long as

necessary without any detrimental effects (as in our case, the tissue was kept for one year prior to injection). Since the dye is not taken up by other cells, it has resulted in quite specific labeling. Once the bulk of the data can be analyzed, definitive anatomical comparisons will be feasible.

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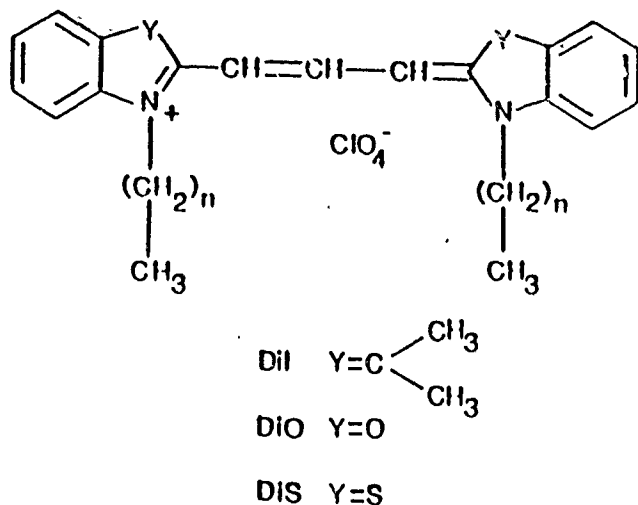
Fig. 1 Structural composition of
carbocyane dye, DiI and DiO.
They are all composed of the
same basic structure with
variations only at the Y
position.(Honig and Hume,87)
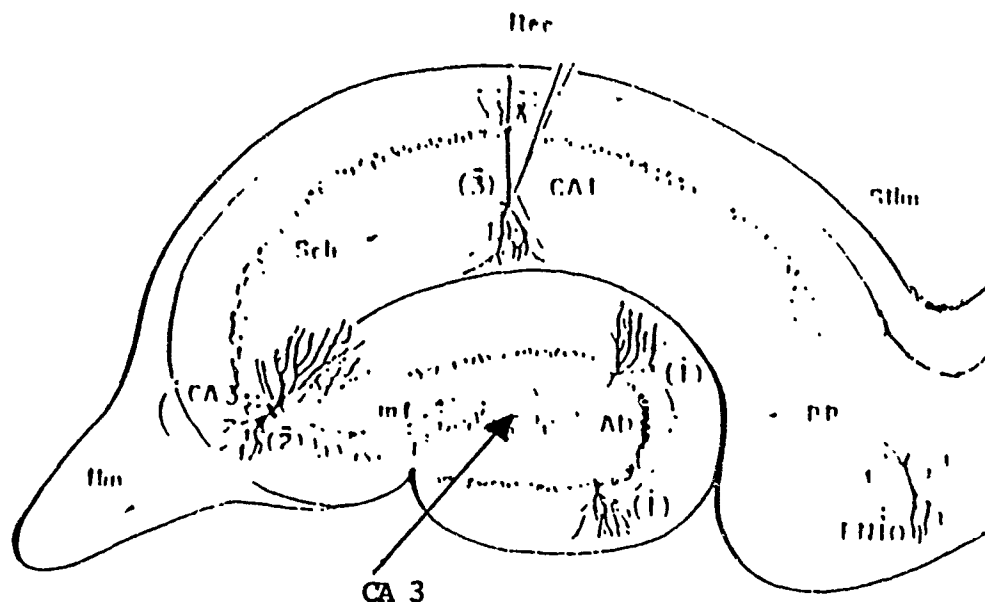
Fig. 2 For the MK-801 experiment, the area of injection
was CA3.

Fig. 3   Projection labeled with DiI.   [10X mag.]
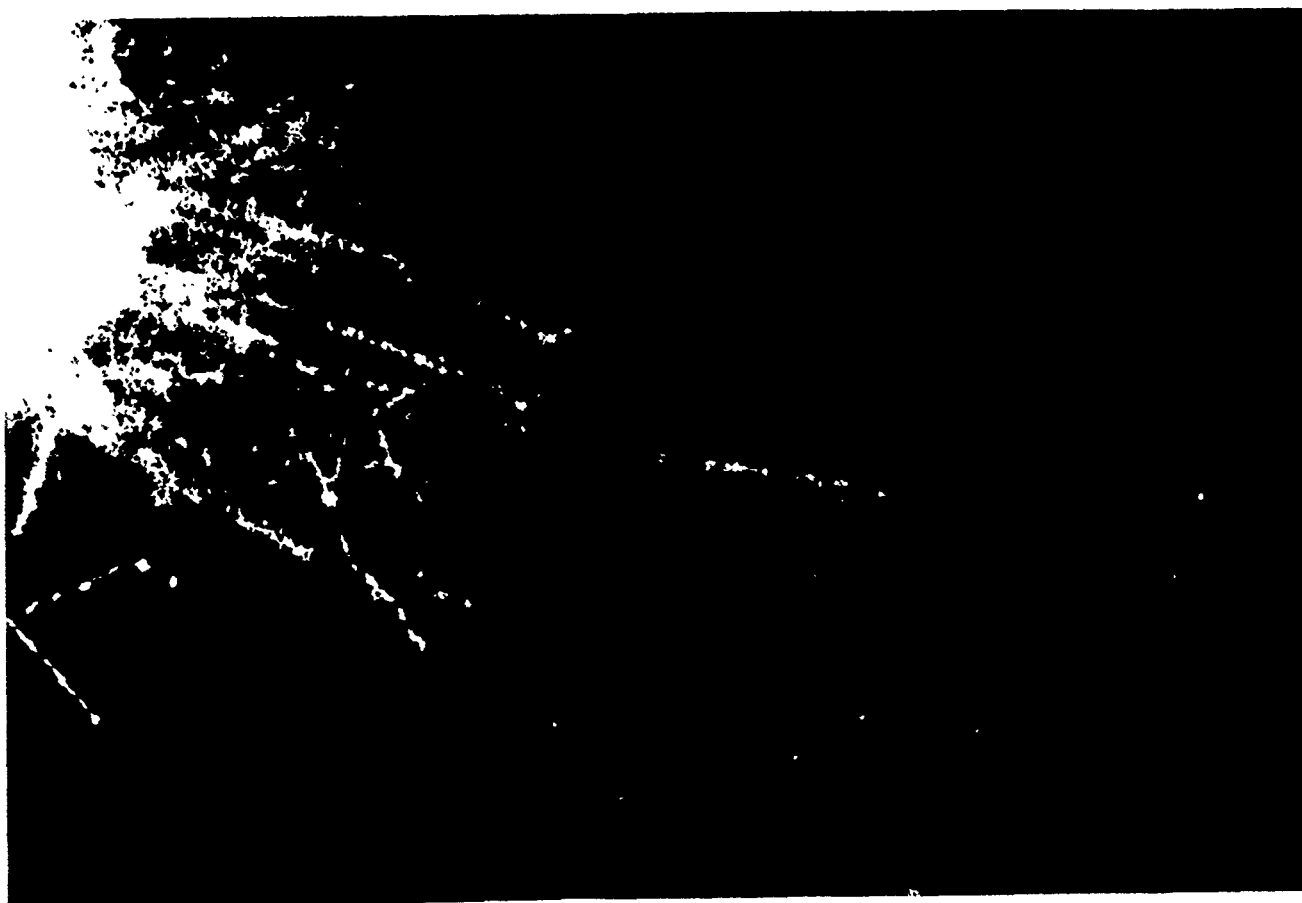
Fig. 4   Labeled projections in CA3 area.   [10X]

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FINAL REPORT

TEMPERATURE EFFECTS ON ERYTHROCYTE SEDIMENTATION RATES, CELL VOLUMES AND VISCOSITIES IN MAMMALIAN BLOOD.

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TEMPERATURE EFFECTS OF ESR. CELL VOLUMES AND VISCOSITIES: FINAL REPORT

Professor W. Drost-Hansen

ABSTRACT

Erythrocyte sedimentation rates and erythrocyte and platelet volumes of blood from 13 different species of mammals have been found to change abruptly near 46 - 46°C. The often dramatic drop in sed rates for temperatures above 45° reflect a histologically proven change in shape of the red cells from biconcave disks to nearly spherical. This change in morphology prevents rouleaux formation and thus lowers the sed rate. Furthermore, the viscosity of blood plasma increases rapidly and abruptly above the critical temperature of 45°C thus further lowering the sed rate. Finally, even resuspended erythrocytes in the absence of the plasma proteins show markedly reduced settling rates above 45°C. Abrupt changes are also seen in some parameters near 30°C; these and the 45°C anomalies reflect the effects of structural changes in the vicinal water associated with both the cells and the biopolymers in solution. This interpretation is further supported by notable thermal anomalies seen in the viscosities of a variety of polymers in aqueous solution, including both synthetic model polymers and naturally occurring biopolymers (such as BSA and fibrinogen.)

INTRODUCTION

Adding EDTA or citrate to whole, freshly drawn blood prevents clotting; the erythrocytes stay suspended in the plasma for varying lengths of time until they slowly settle (hindered settling). The rate of settling may be observed for periods of time up to several hours. The distance settled in one hour at 25°C (room temperature) is the quantity used clinically as "the sed rate" (ESR) (Maile, 1977). In normal, healthy individuals, the ESR is anywhere from a few mm to 10mm. Notably larger values (say,>15-20mm) suggest some type of pathology. The ESR has been in use for almost 70 years and is probably still the most frequently performed, clinical lab test in the world; a vast literature exists on the subject.

The initial objective of our research was to measure the effects of temperature of the sed rate; very little attention has been paid to this aspect in the past. Two years ago, the suggestion was also made that the temperature coefficient of the ESR (d[ESR]/dT) may contain some diagnostically significant information presently missed.

To facilitate making measurements at closely spaced temperature intervals, a Linear Temperature Gradient Incubator (TGI - i.e., a "polythermostat") has previously been developed by the Senior Author and his collaborators (Drost-Hansen, 1981). A number of commercial models of the TGI have been available for some time; however, these units are mostly designed

for studies on systems requiring agitation, such as bacterial growth, cell cultures, enzyme reactions and adsorption studies. The TGI unit employed in the present study is "homemade" and allows for arranging two sets of 30 standard-sized sample tubes in rigid, vertical positions making it highly useful for sedimentation studies.

As with the commercial, more sophisticated models, the principle is the same: a heavy, rectangular aluminum bar (8 x 20 x 150 cm, weighing about 100 kg) is carefully insulated in a support box. One end of the bar is provided with electric heating elements and a thermoregulator to maintain any preselected, constant temperature. The heat is dissipated by conduction through the bar; at the cold end a plastic chamber serves as a reservoir for a circulating cold liquid, the temperature of which is kept constant. As lateral heat losses from the bar are kept to a minimum, an essentially linear temperature gradient is set up in the bar. Along the length of the bar are two sets of 30 "wells", equidistantly spaced. Each well is large enough to accommodate a standard culture tube (15cm long and 18mm diameter). The long term stability (constancy) of the TGI has proven highly satisfactory: except possibly for wells #30 and #1, temperature fluctuations in any well over a period of days(or weeks) have been within $0.1^{o}C$., or less. Considering that a thermal gradient about $0.4^{o}C$ exists across each well, fluctuations of $\pm 0.1^{o}C$ in any one well are insignificant.

Hematology parameters were determined with a Baker System 9000 Cell Counter which is calibrated for both human and animal blood samples. In repeat experiments, the reproducibility was found to be excellent, usually with 1% in cell numbers (both RBC and platelets) and better than 1% in cell volume measurements.

In the present study standard Wintrobe tubes were placed directly in the wells of the TGI using rubber stoppers assuring as nearly vertical positioning as practical. In separate experiments with the Wintrobe tubes, the rate of temperature equilibration was determined: after about 15 minutes the temperature of the blood has essentially reached the equilibrium temperature. As most sedimentation experiments were carried out over periods of two to four hours, the initial lack of equilibration (at the higher temperatures) is not significant. For sedimentation and all volume measurements using the TGI, EDTA was used as anticoagulant. A 0.25 molar stock

solution of disodium EDTA was added to the freshly drawn blood; 1ml EDTA stock solution per 50 ml blood - i.e., a 2% dilution of the whole blood.

SEDIMENTATION RATE DATA

Figures 1-8 shows some typical sed rates as a function of temperature. In ALL cases studied so far, the rate of settling decreases abruptly above 45 ($\pm$1)$^{\circ}$C. In some cases, anomalies are seen also near 30($\pm$1)$^{\circ}$C. (This latter feature is sometimes brought out more clearly in graphs of the logarithm of the sed rate versus temperature - i.e., a quick and dirty approximation to an Arrhenius graph). To date, sed rate measurements have been made on blood from the following mammals: humans, chimpanzee, baboon, dog, cat, horse, cow, goat, sheep, rabbit, pig, llama, and killer whale; plus blood from one bird, the emu (!)

The dynamics of the erythrocyte sedimentation process is extremely complicated. Little progress has been reported on the construction of suitable models for the process. Among the many difficulties is the tendency for RBC rouleaux formation - a process notably influenced by the presence in the blood of large, usually asymmetric, macromolecules such as fibrinogen (and, via this mechanism reflecting possible pathological conditions in the subject). The rouleaux formation is primarily responsible for the enhanced settling rate (compared to isolated, resuspended erythrocytes).

It is generally accepted that exposure to high temperatures leads to changes in the shape of the erythrocytes. Thus, Whittam (1964) quotes Ponder to the effect that heating red cells "causes profound morphological changes of which perhaps the most striking is the irreversible change to spherical form on heating a few minutes at 48°C. If indeed this morphological change should occur as well as the result of exposure for 30 (or more) minutes to temperature of 45°C (and above), then it is hardly surprising that the sed rate should drop abruptly near this critical temperature as the change from the normal, bi-concave disk shape to spherical will prevent the rouleaux formation normally responsible for large sed rates.

The obvious next question is: what causes the abrupt change in RBC morphology at 45-48°C? (i.e., the change from bi-concave disk to near spherical). The answer is that it is likely to be

Fig. 1 — Distance sedimented vs. temperature. Specimen: W.R.P. Data: 6-5-91; analyzed: 6-7-91

Fig. 2 — Distance sedimented vs. temperature. Specimen: R. McN. Data: 6-12-91; analyzed: 6-15-91
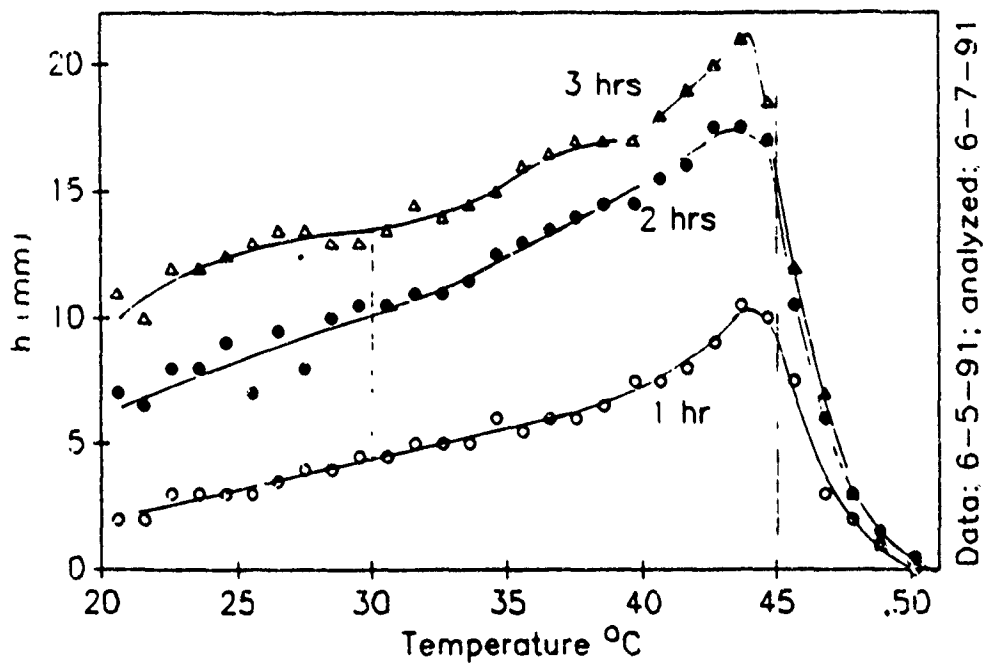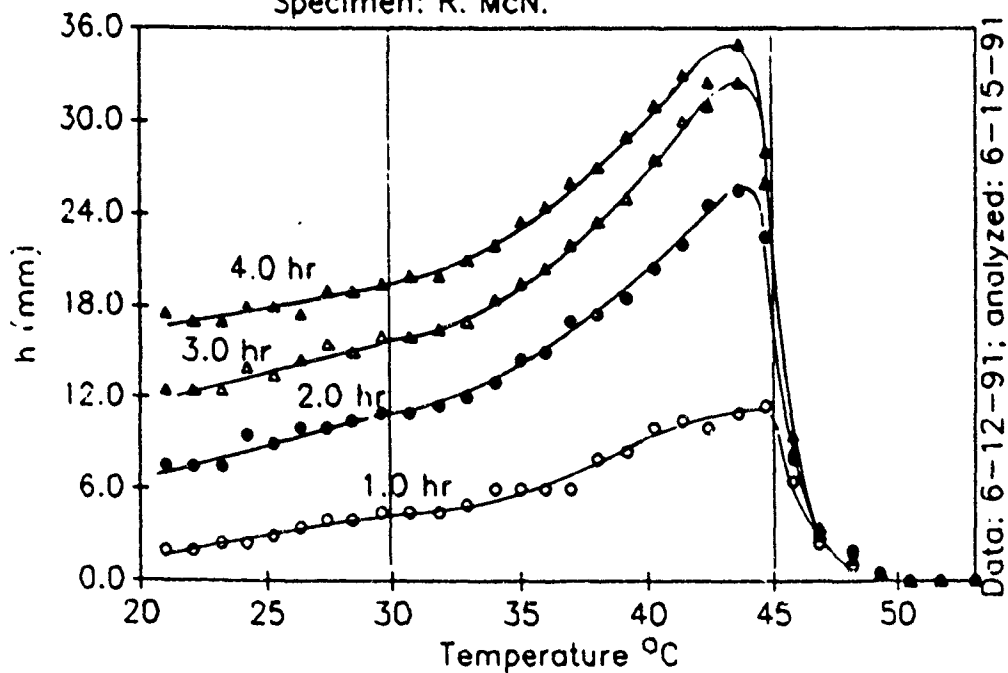
Fig. 3   Distance sedimented vs. temperature
Specimen: W. D–H.
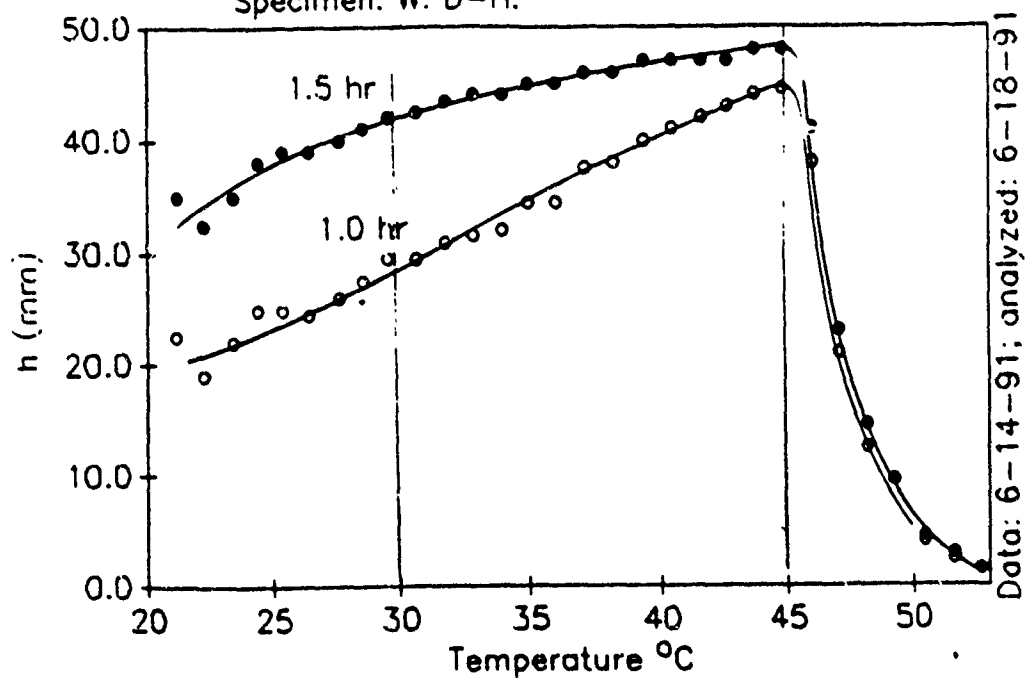
Fig. 4   Distance sedimented vs. temperature
Specimen: chimpanzee

34-6
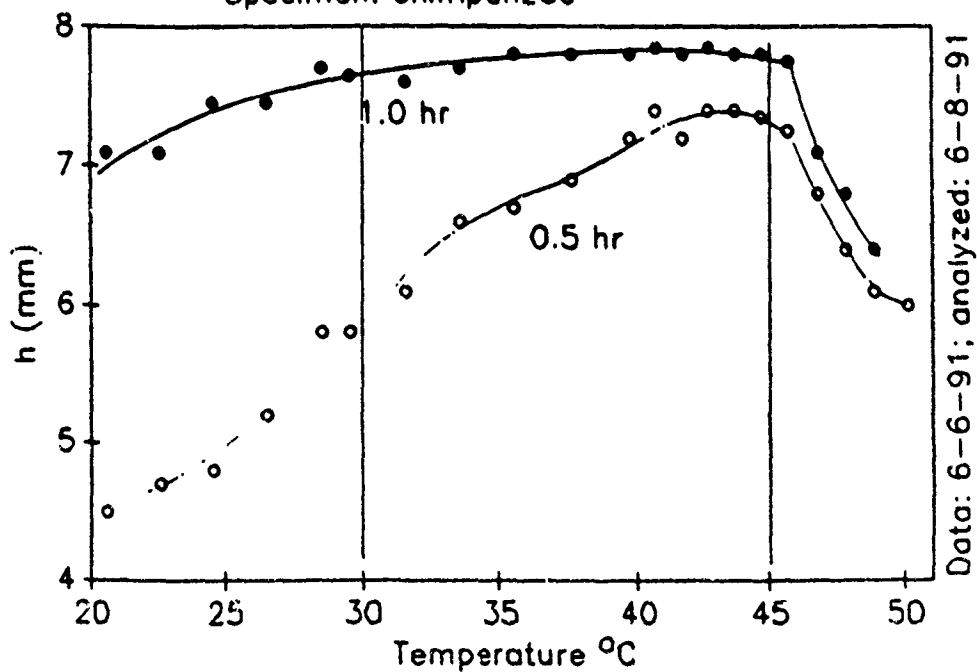
Fig. 5 **Distance sedimented vs. temperature**
Specimen: baboon
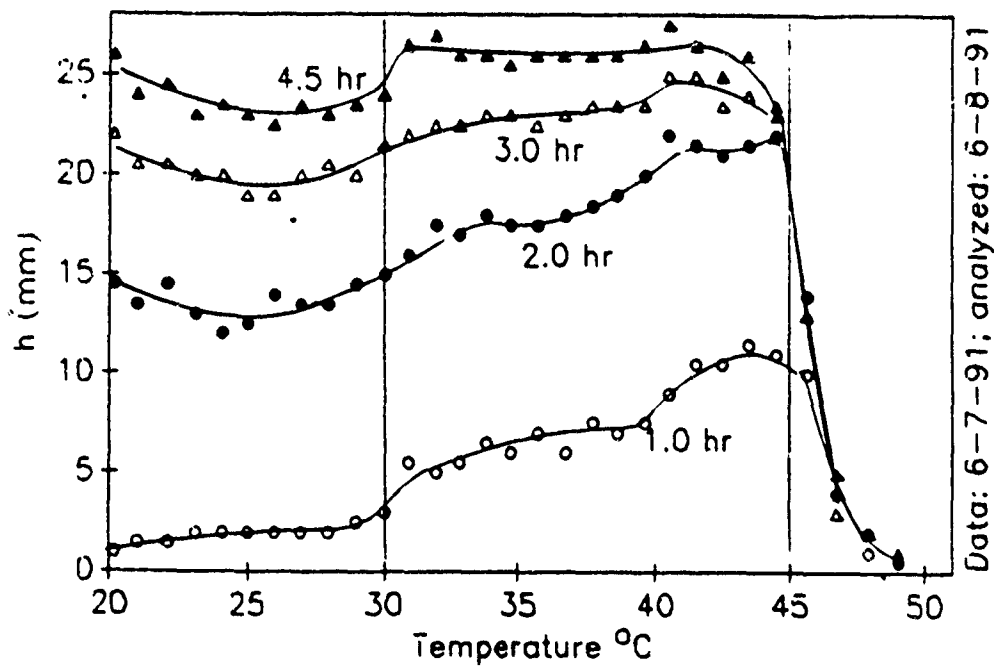
Fig. 6 **Distance sedimented vs. temperature**
Specimen: pig
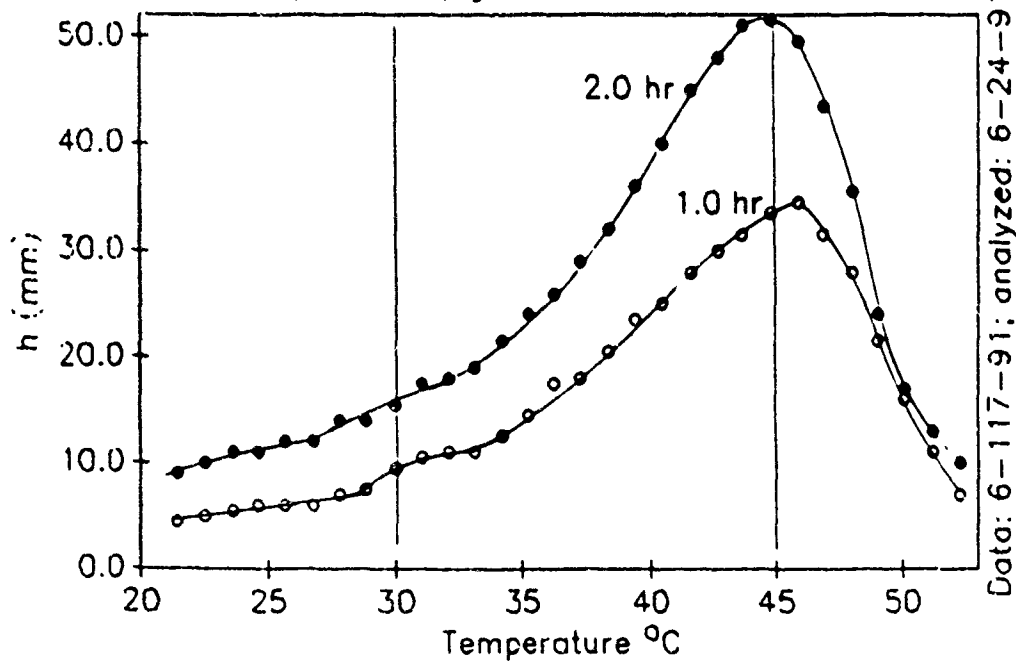
the vicinal water. Thus, if the vicinal water contributes to the stability of the RBC shape via the vicinal hydration of some structural elements (for instance the microtubles, intermediate filaments or microtrabecular network) destabilization is likely to occur near 44-45°C when the vicinal water changes form one type of structure to whatever structure is stable above this critical temperature range. Furthermore, the rheological character of the RBC interior will change as the temperature is raised past the transition temperature range: the viscosity of all the polymers studied so far changes, often abruptly, at or near the vicinal water transition temperatures (see below).

MEAN CELL VOLUMES (RBC AND PLATELETS)

In most attempts to develop theories of hindered settling, the point of departure is the Stokes fall of a single, rigid, spherical particle (far removed from the confining surfaces and neighboring particles) in a Newtonian fluid: $v = 2\pi r^2 \Delta \rho / 9\eta$. The conceptual gap between the model assumptions and the nature of real-life whole blood is staggering. Nonetheless, because of the r^2 dependence of the Stokes fall velocity it was of interest to measure the volumes of the erythrocytes as a function of temperature over the same range as used for the settling rate measurements. Figures 9-12 show some typical results of the volume measurements. In humans, a large anomaly is seen near 45°C and similar anomalies are seen in the blood from variety of other mammals, but not observed with some (such as cat, goat, etc. see Figures (13-19). It should be noted that temperatures above 45°C are highly "unphysiological" as this temperature is (almost invariably) the thermal death limit for all mammals (and birds) (Drost-Hansen, 1971).

The experimental approach used for the erythrocyte volume measurements also allows determinations of the (apparent) platelet volumes. Some typical results of such measurements are shown in Figures 20, 21, and 22. The trends in the data are remarkably reproducible; however, the actual numerical values are subject to much uncertainty because of possible interference from spurious small particle fragments as well as platelet aggregation. We have observed platelet aggregation to increase dramatically at 45 to 46°C.

Fig. 7   Distance sedimented vs. temperature
Specimen: dog
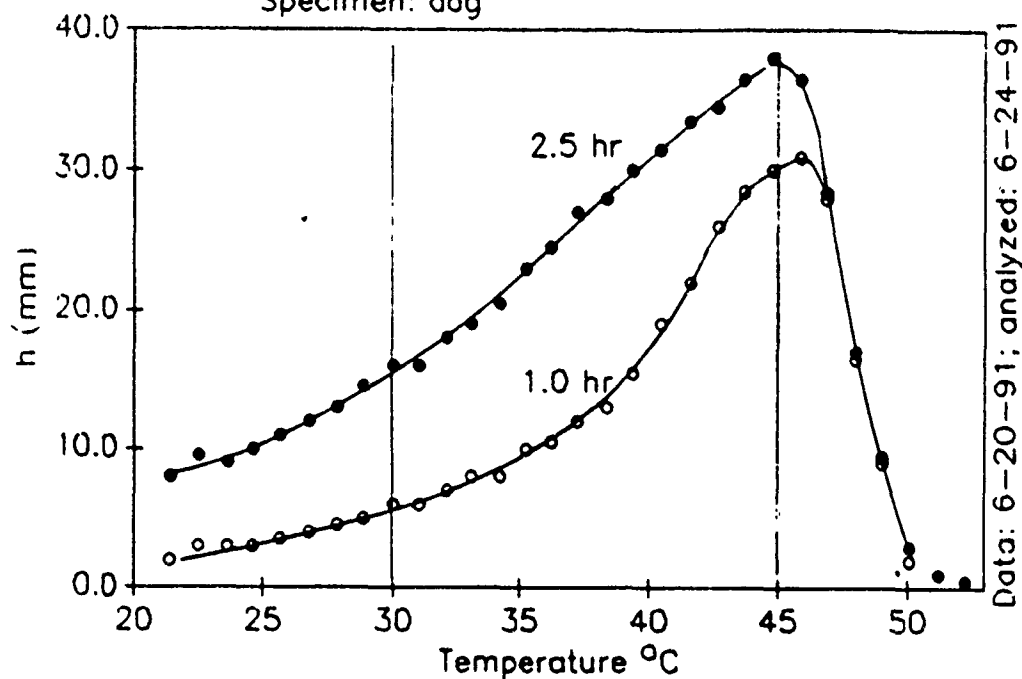
Fig. 8   Distance sedimented vs. temperature
Specimen: cat
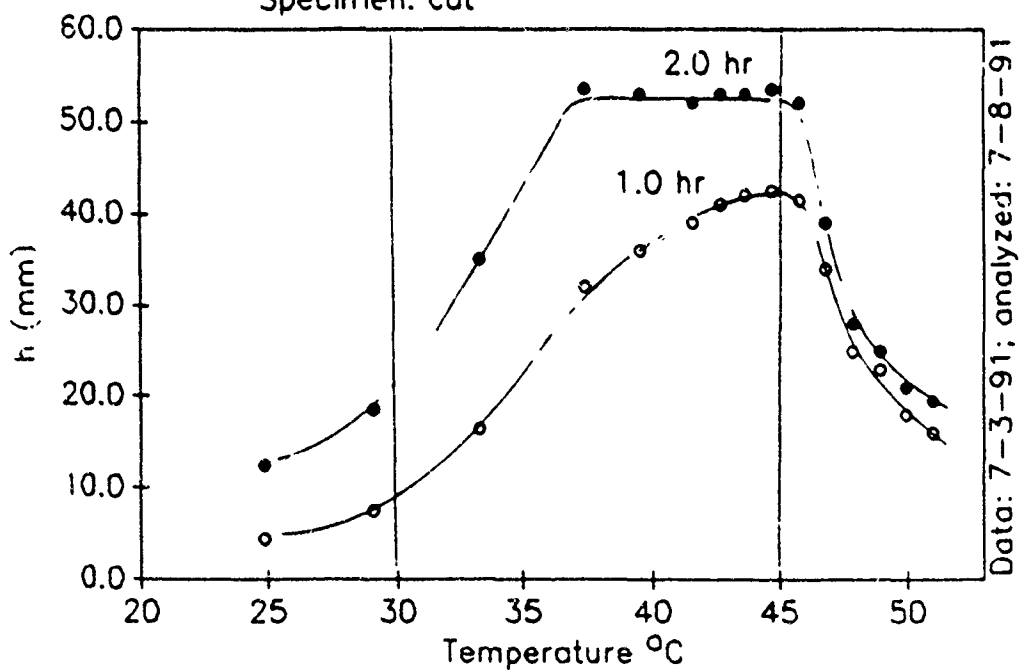
Fig. 9   Mean erythrocyte volume vs. temperature
Specimen: W.R.P.   Incubation: 4 hours

Data: 6-5-91; analyzed: 6-8-91
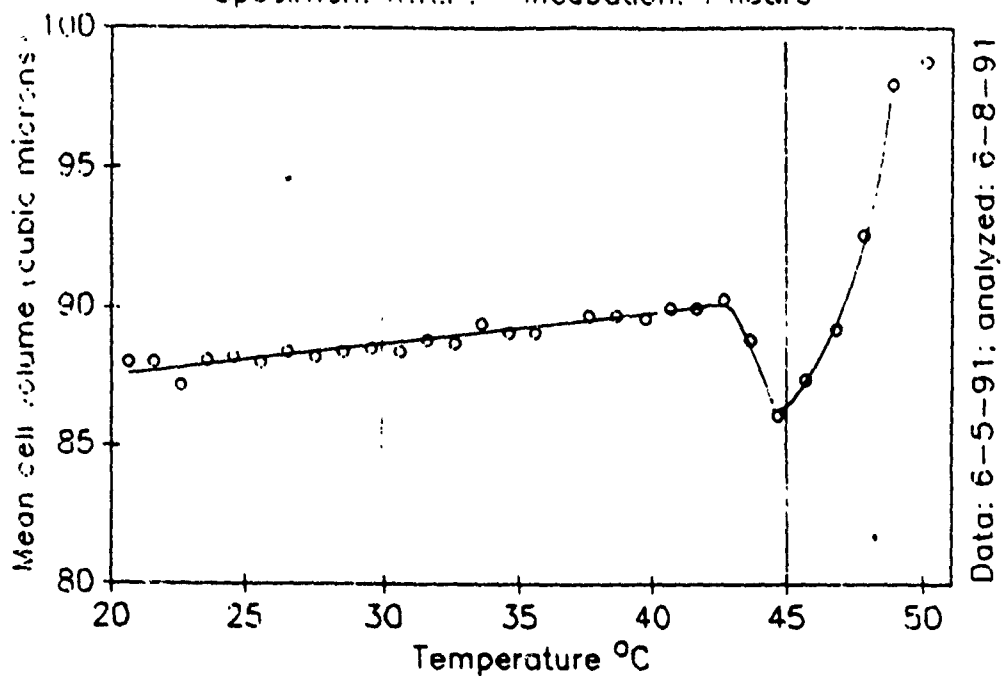
Fig. 10   Mean erythrocyte volume vs. temperature
Specimen: R. McN.   Incubation: 4.5 hours

Data: 6-12-91; analyzed: 6-15-91
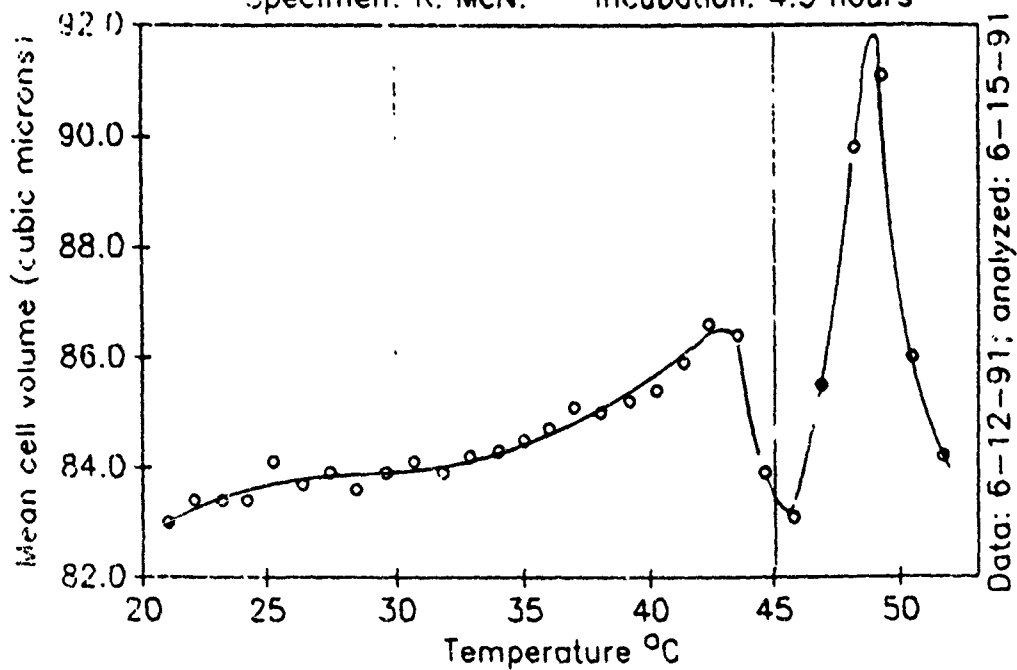
Fig. 11   Mean erythrocyte volume vs. temperature
Specimen: W. D-H.   Incubation: 2.0 hours
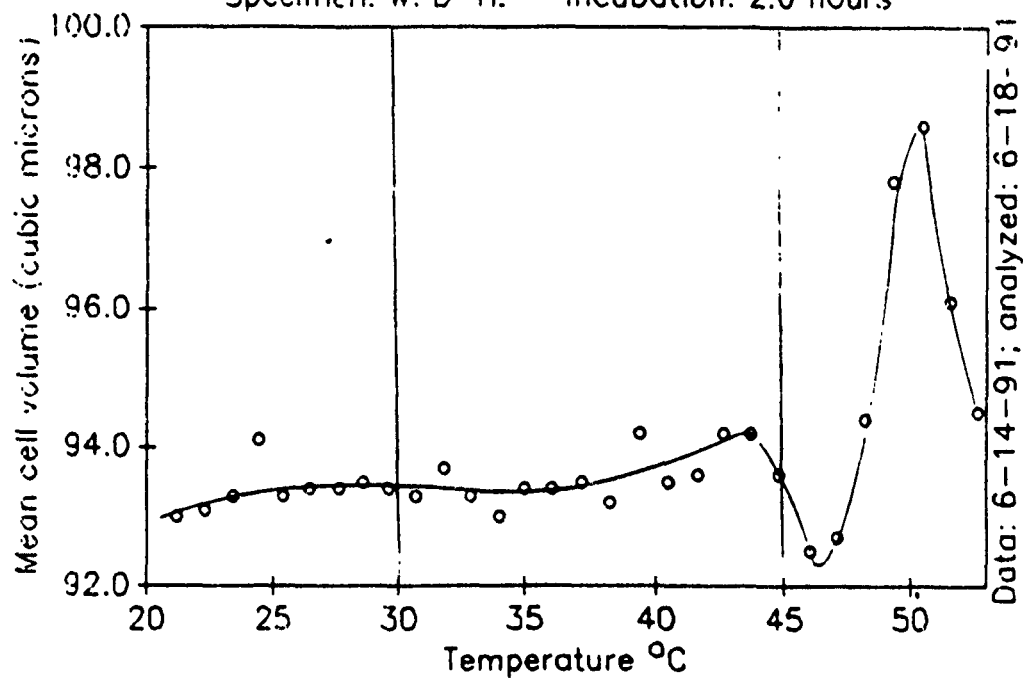
Fig. 12   Mean erythrocyte volume vs. temperature
Specimen: pig   Incubation: 2 hours
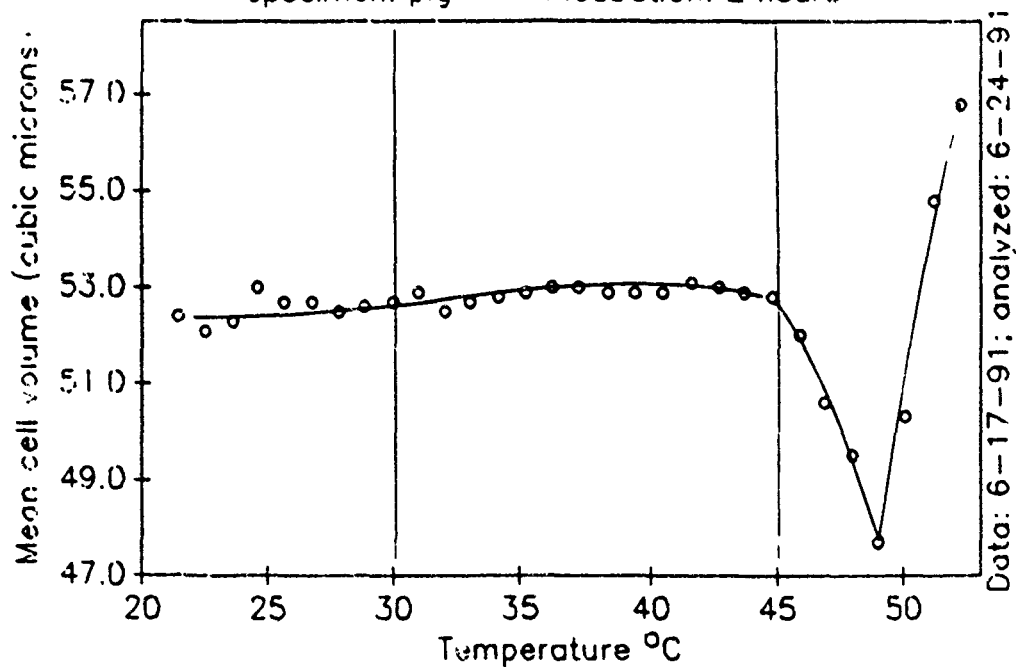
Fig. 13 Mean erythrocyte volume vs. temperature
Specimen: cat   Incubation: 2.0 hours

Data: 7-3-91; analyzed: 7-8-91
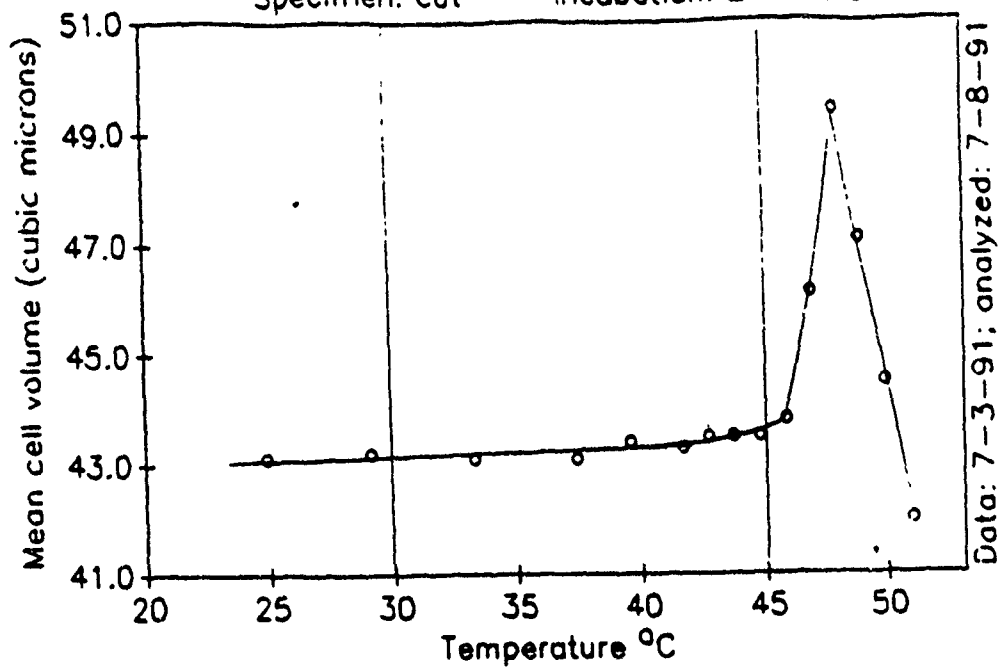
Fig. 14 Mean erythrocyte volume vs. temperature
Specimen: chimpanzee   Incubation: 2 hours

Data: 6-6-91; analyzed: 6-8-91
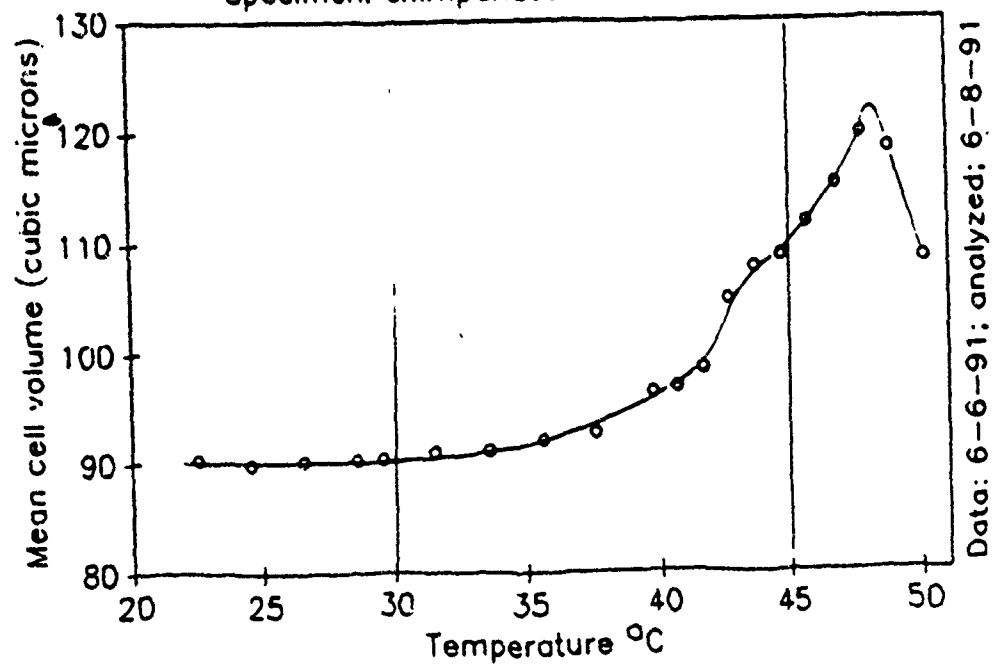
Fig. 15   Mean erythrocyte volume vs. temperature

Specimen: baboon   Incubation: 4 hours
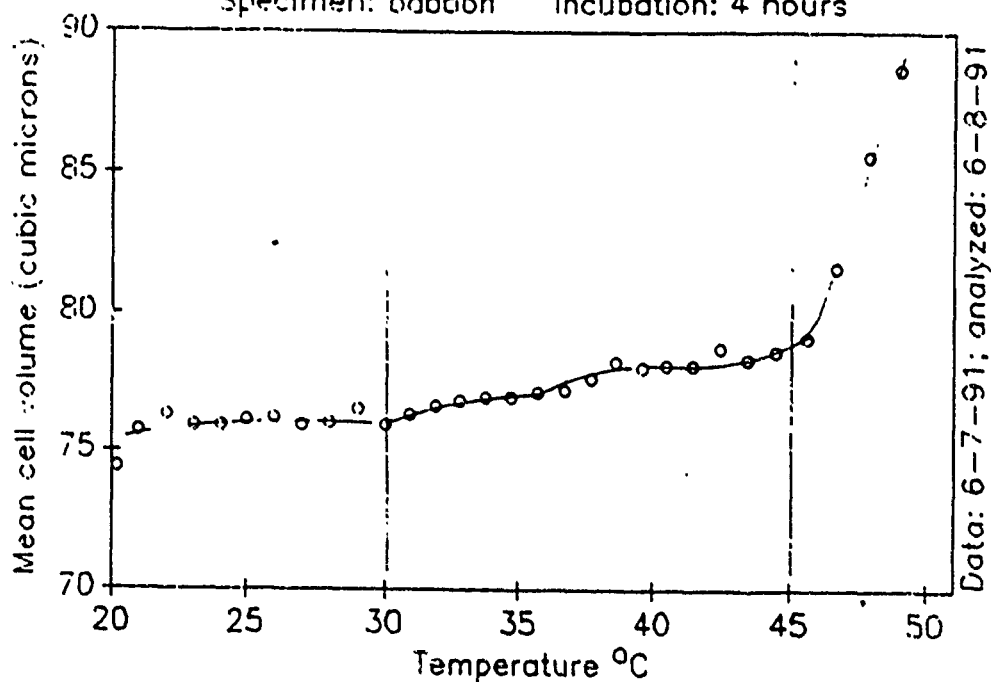
Fig. 16   Mean erythrocyte volume vs. temperature

Specimen: cow   Incubation: 2.0 hours
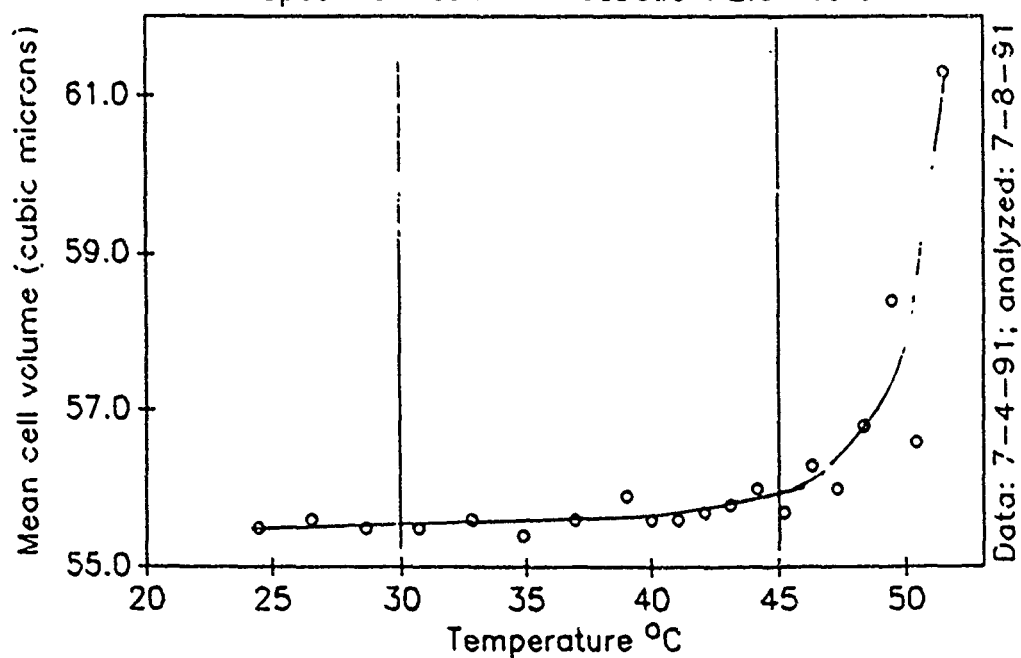
Fig. 17 Mean erythrocyte volume vs. temperature
Specimen: goat   Incubation: 2.0 hours

Data: 6-11-91; analyzed: 6-15-91
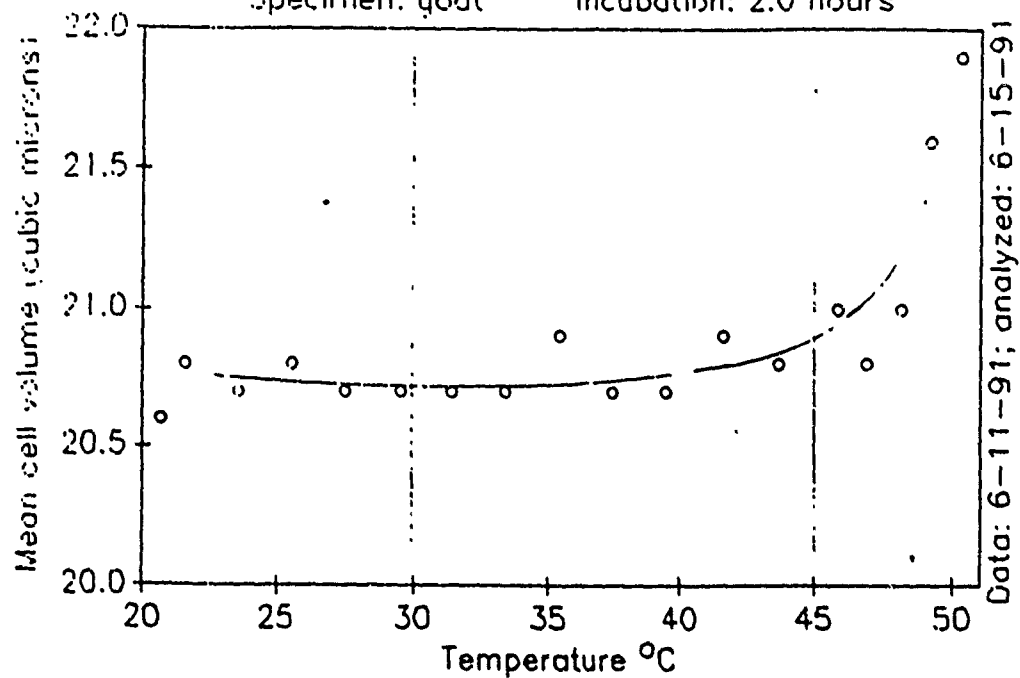
Fig. 18 Mean erythrocyte volume vs. temperature
Specimen: sheep   Incubation: 3.0 hours

Data: 7-3-91; analyzed: 7-8-91
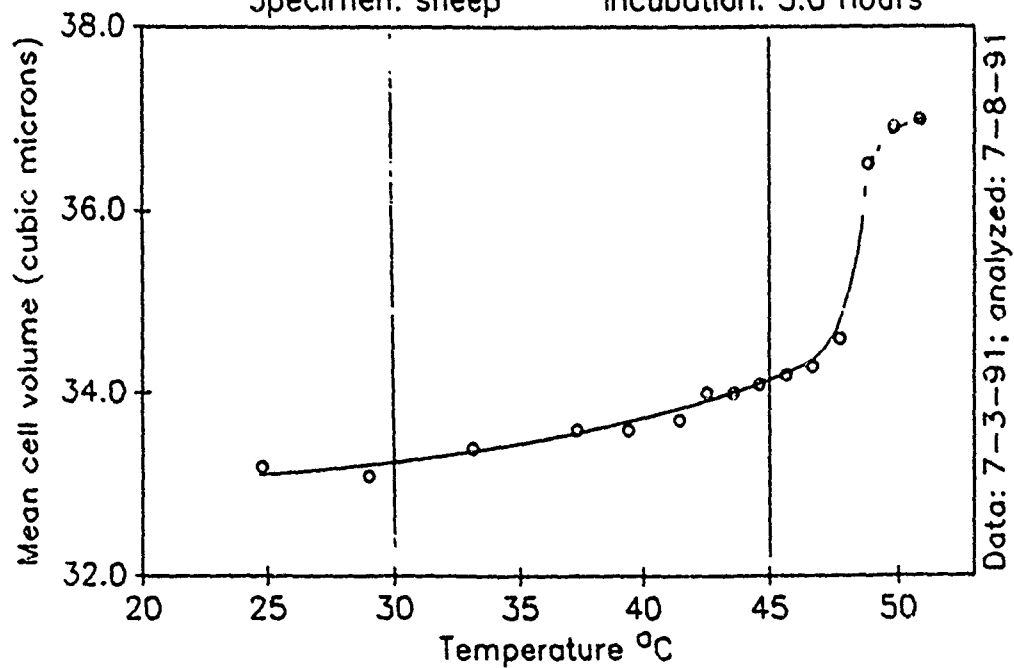
Fig. 19   Mean erythrocyte volume vs. temperature
Specimen: llama   Incubation: 3.0 hours
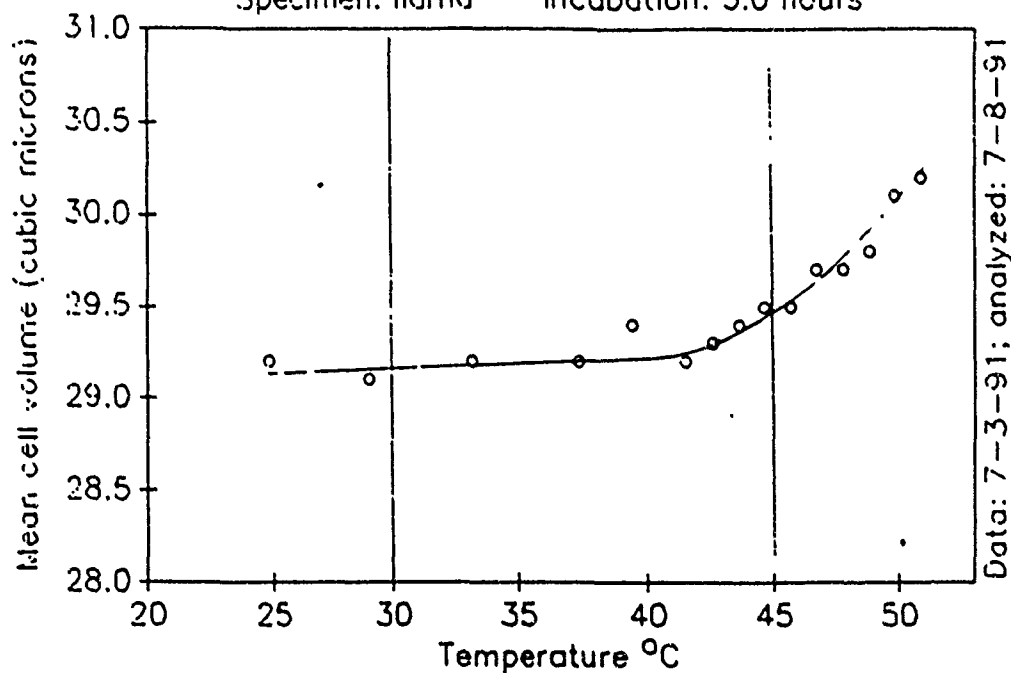
Fig. 20   Mean platelet volume vs. temperature
Specimen: W. D-H.   Incubation: 2.0 hours
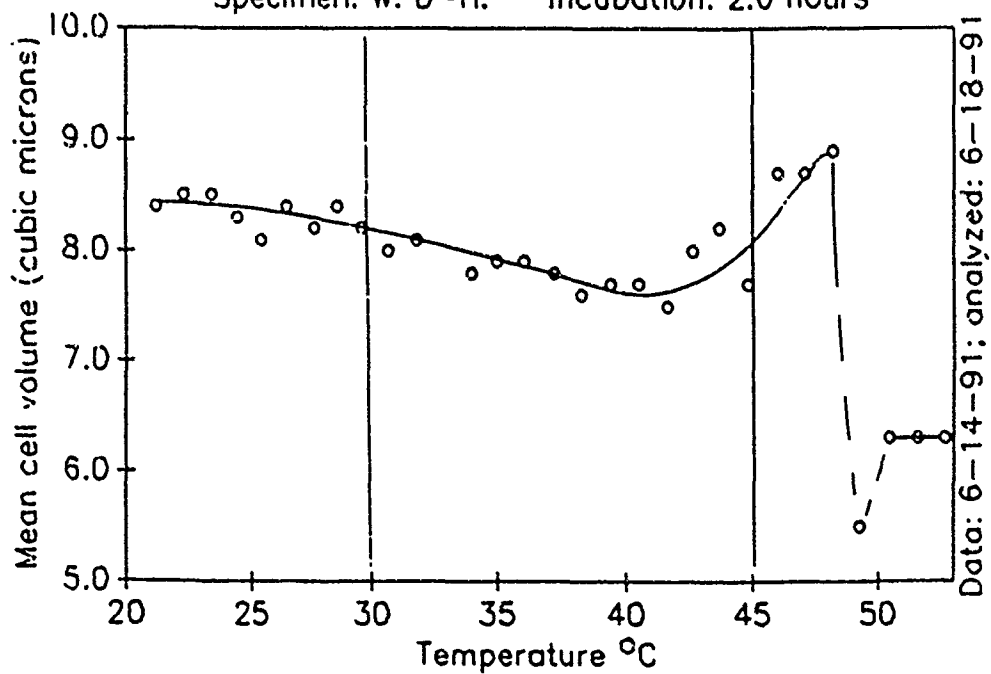
Fig. 21   Mean platelet volume vs. temperature
Specimen: chimpanzee   Incubation: 2 hours

Data: 6-6-91; analyzed: 6-8-91
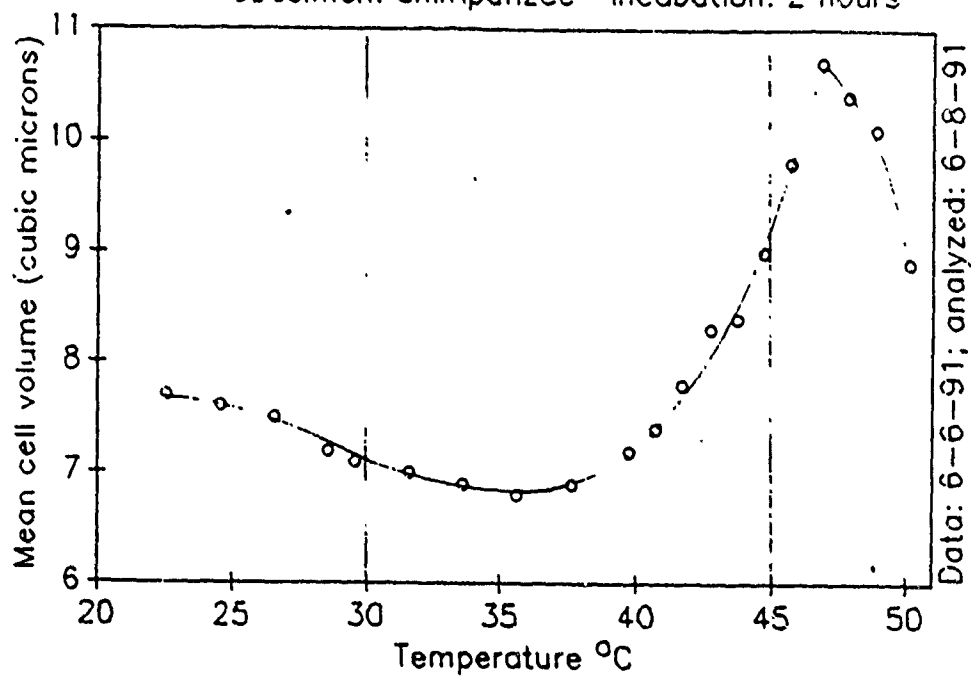
Fig. 22   Mean platelet volume vs. temperature
Specimen: dog   Incubation: 17.0 hours
Resuspended RBC

Data: 6-20-91; analyzed: 6-27-91
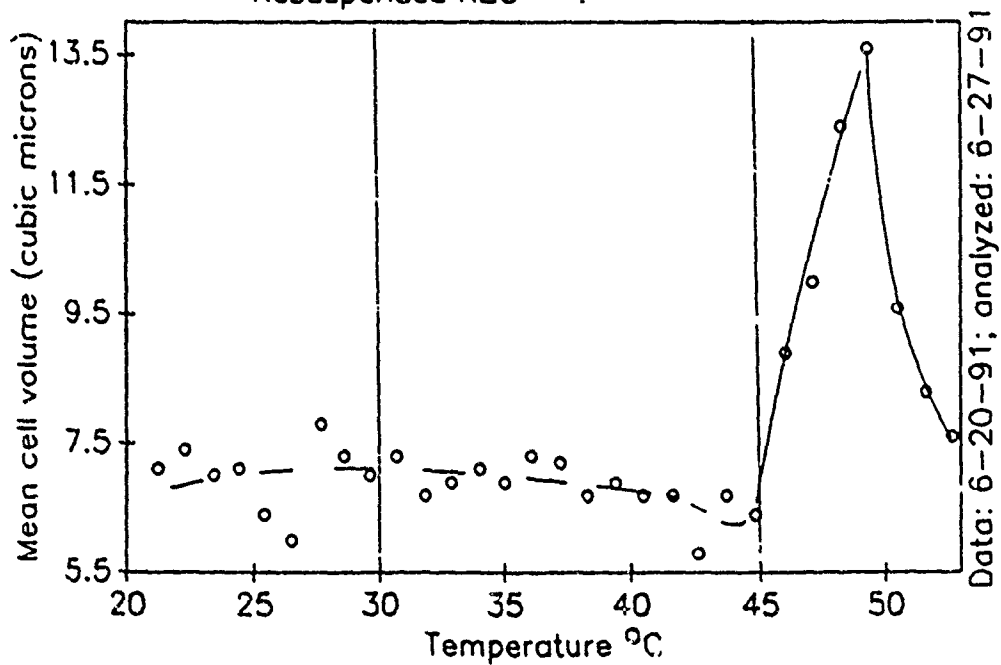
DYNAMICS OF SEDIMENTATION

We are investigating the possible mechanisms involved in the dramatic changes in the sed rate of the erythrocytes in whole blood near 45°C. The main question is: besides the likely change in extent of rouleaux formation, does the 45°C drop in sed rate reflect a sudden increase in the viscosity of the blood plasma - presumable reflecting dramatic changes in viscosities of aqueous protein solutions - or does the change in sed rate reflect some intrinsic feature of the erythrocytes themselves? The answer is rather surprising: both aspects are found to contribute! Erythrocytes were isolated from whole blood by centrifuging and repeated washings (3 washings with lactate-Ringers solution) and redispersed in the isotonic solution. Figures 23, 24, 25 and 26 show the settling of the isolated erythrocytes as a function of temperature. The rate of settling is far lower than in whole blood; this is presumably due to the removal of the proteins responsible for the rouleaux formation which is the primary mechanism responsible for the high rate of settling of the red cells. However, once again it is seen that the rate of settling drops notably at or just above 45°C. Thus, some aspect of the erythrocytes themselves appear to cause a change near the transition.

Viscosity measurements have been carried out on both the blood plasma isolated from the centrifuged cells as well as on a blood serum obtained from the same donors. The viscosity measurements were made with a Brookfield, Model LVTDV-II viscometer at various shear rates, using the parallel plate measuring technique (see the graphs for the RPM used in each case).

VISCOSITY DATA

Figures 27, 28, 29 and 30 show some of the data obtained for the viscosities of the plasma. An anomaly is frequently seen near 30°C and a large increase in viscosity is observed somewhere above 45°C - but not necessarily right at this temperature. The increase in viscosity is often a factor of ten (or more): no wonder, then, that the rate of settling of the erythrocytes drops off quite dramatically at higher temperatures. (Recall, however, that even the absence of the plasma proteins, the rate of settling of the isolated erythrocytes is notably slowed down above 45°C.

Fig. 23   Distance sedimented vs. temperature
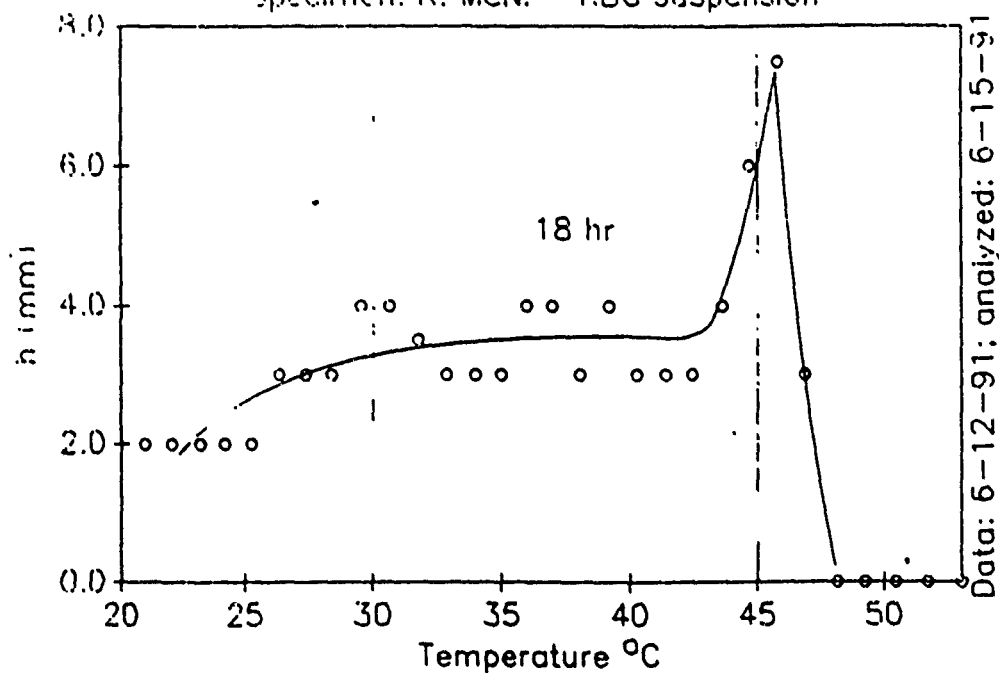Specimen: R. McN.   RBC suspension

18 hr

h (mm)

Temperature °C

Data: 6-12-91; analyzed: 6-15-91

Fig. 24   Distance sedimented vs. temperature
Specimen: W. D-H.   Resuspended RBC

19.5 hr

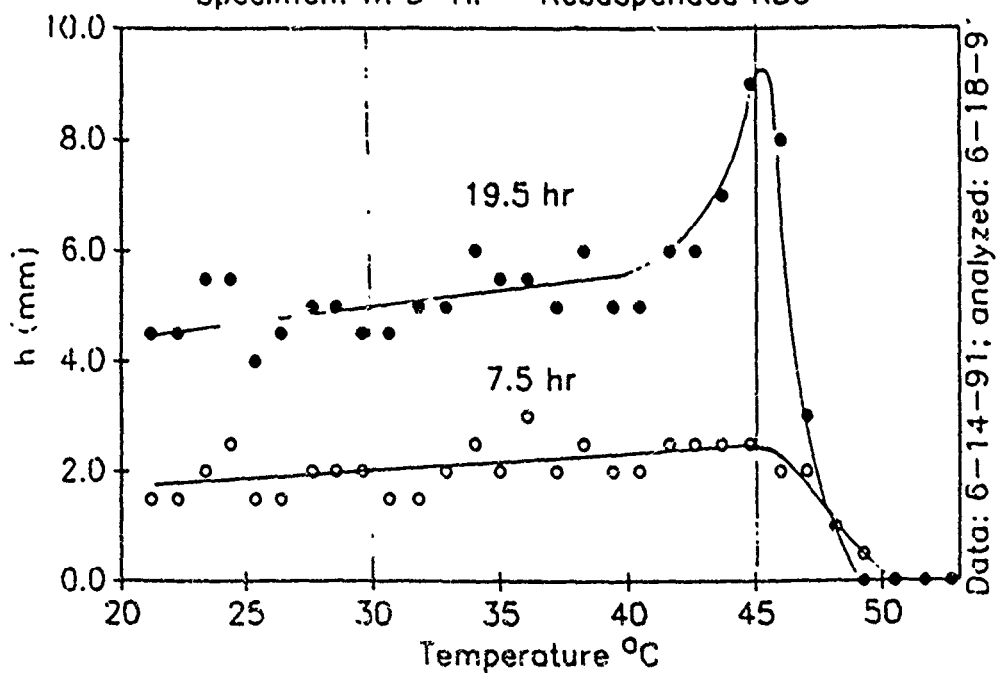7.5 hr

h (mm)

Temperature °C

Data: 6-14-91; analyzed: 6-18-9

Fig. 25   Distance sedimented vs. temperature
Specimen: pig   Resuspended RBC

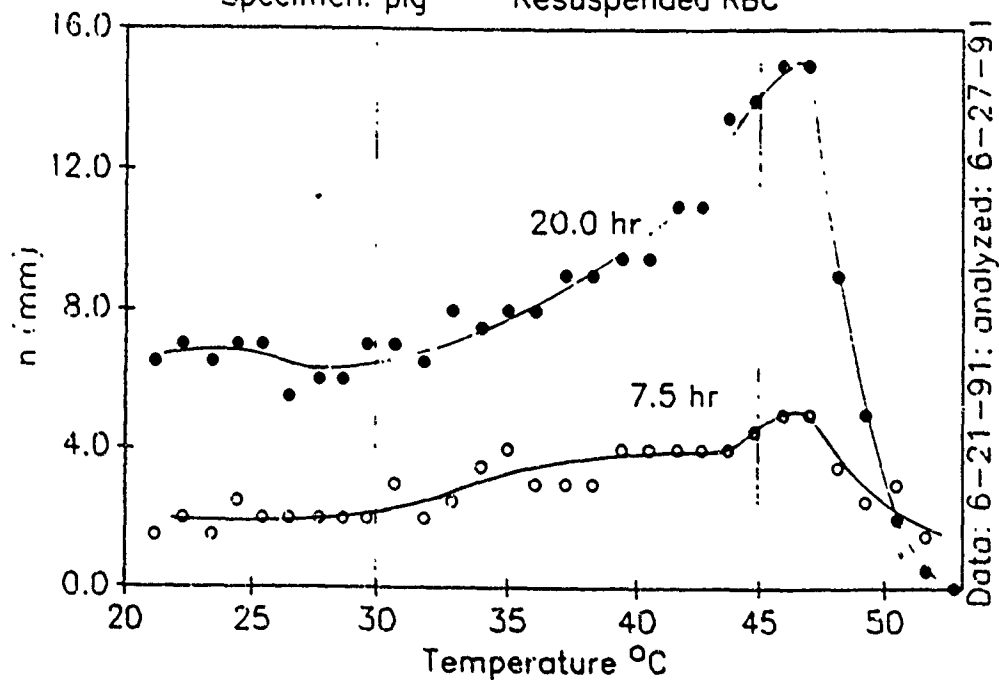
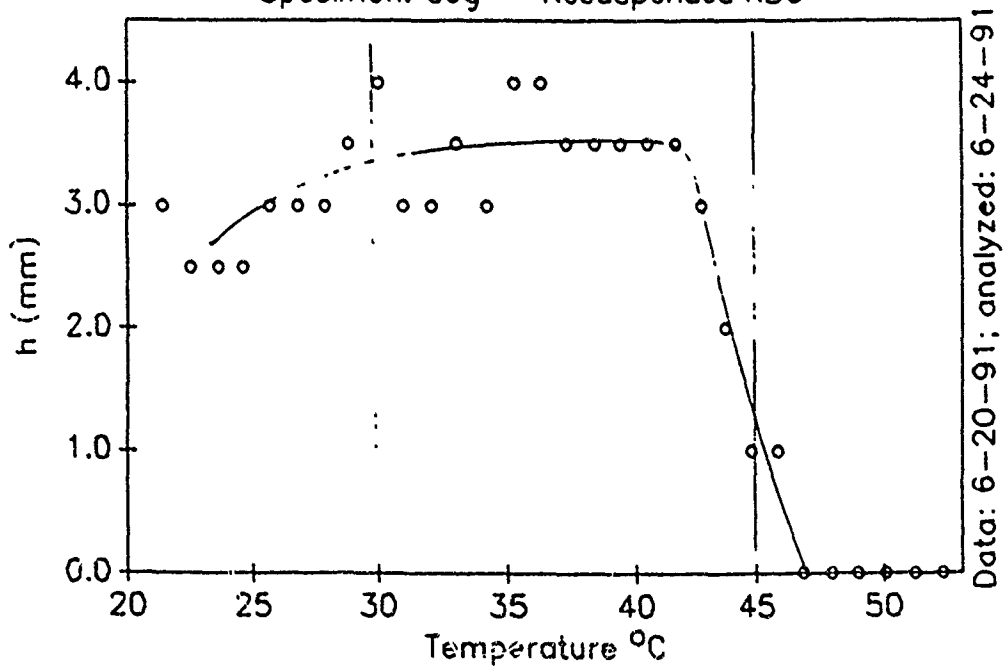Fig. 26   Distance sedimented vs. temperature
Specimen: dog   Resuspended RBC

Fig. 27

Apparent viscosity vs. temperature

Specimen: R. McN.   Fluid: plasma
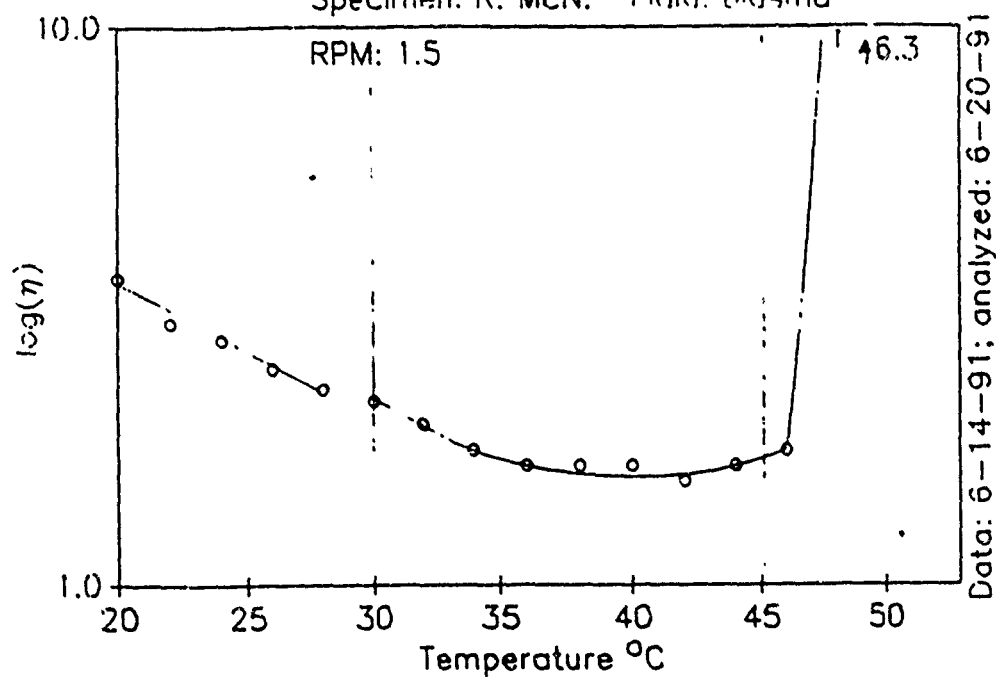
Fig. 28

Apparent viscosity vs. temperature

Specimen: W. D-H.   Fluid: plasma
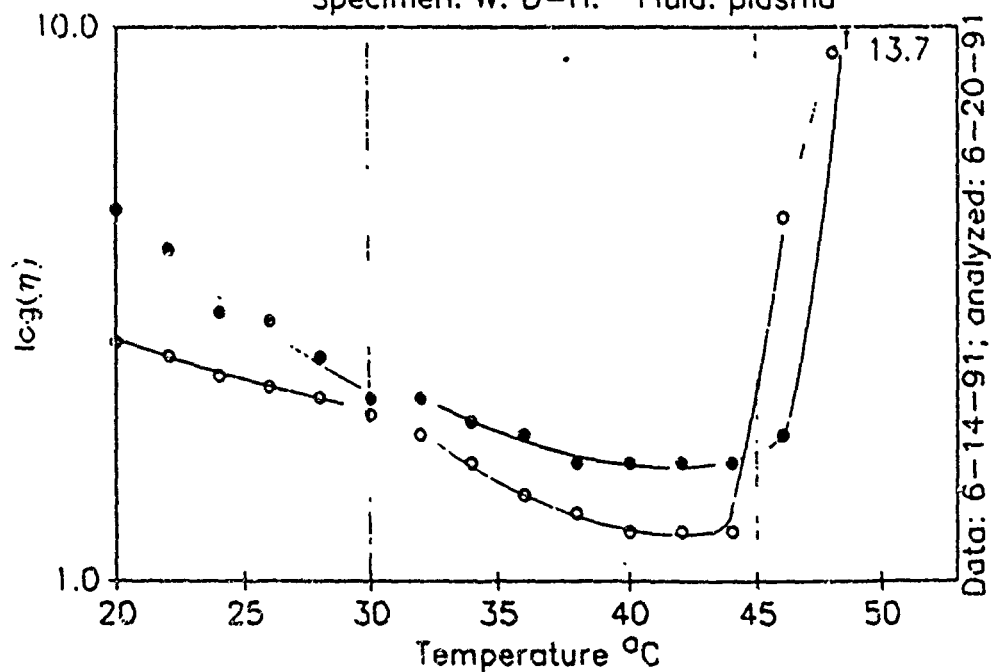
Fig. 29 — Apparent viscosity vs. temperature
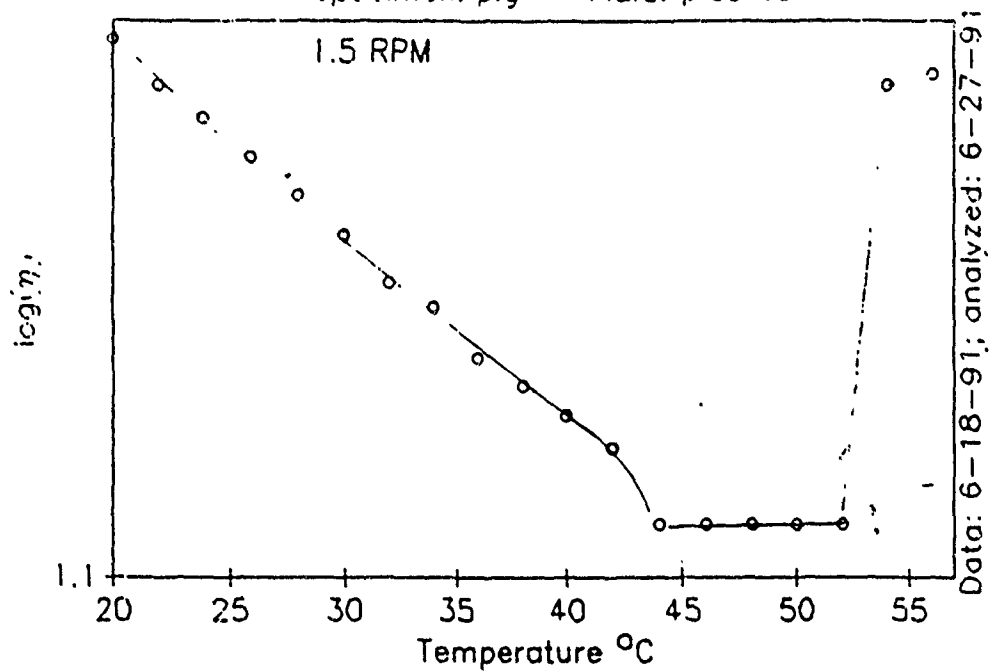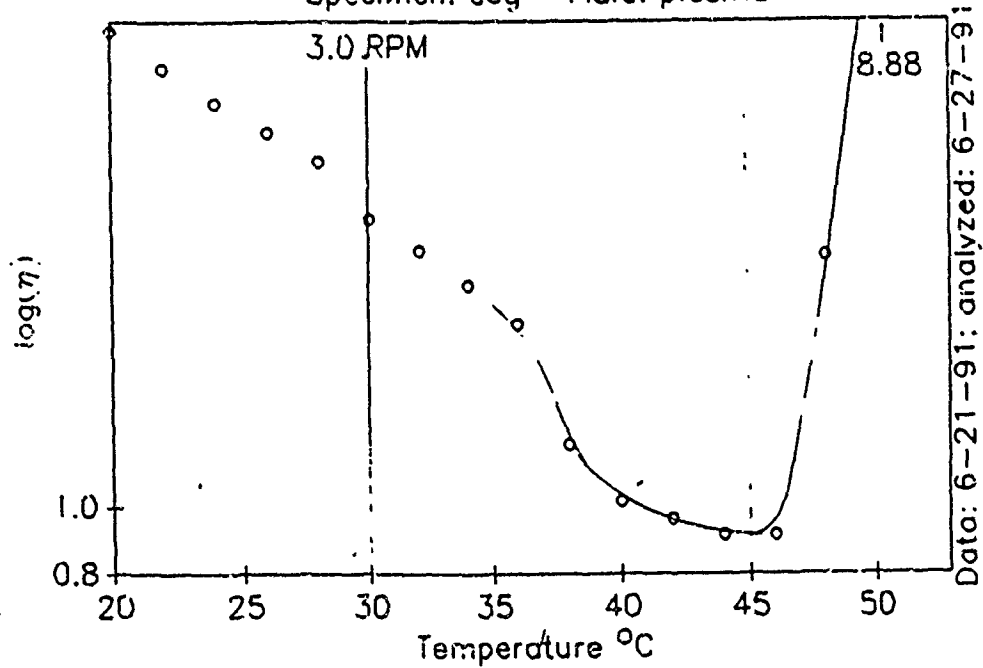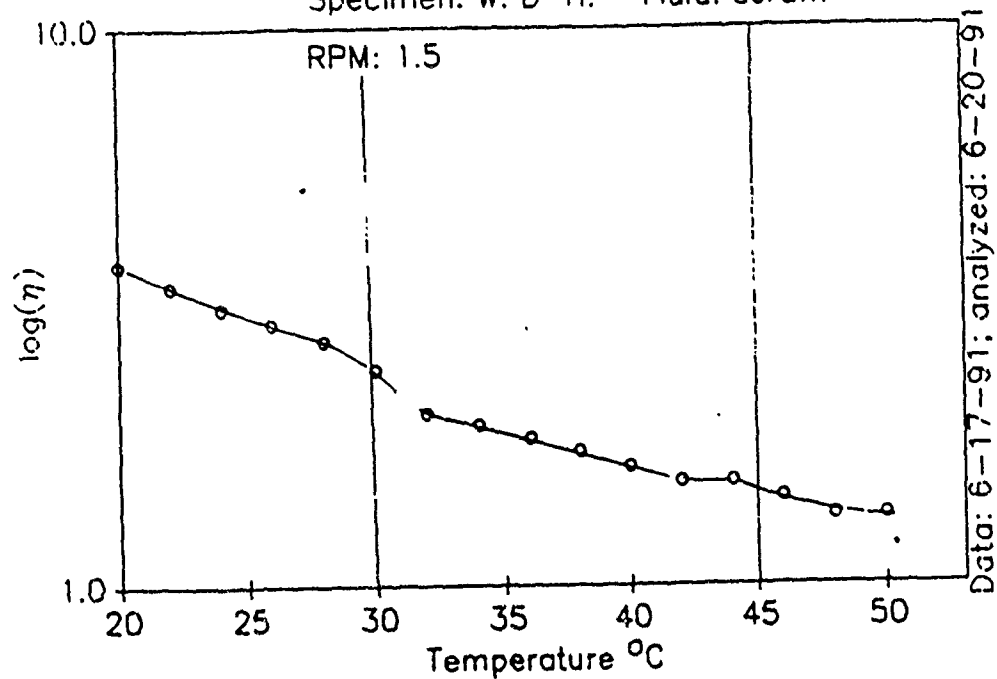Specimen: pig   Fluid: plasma
1.5 RPM

Data: 6-18-91; analyzed: 6-27-91

Fig. 30 — Apparent viscosity vs. temperature
Specimen: dog   Fluid: plasma
3.0 RPM

Data: 6-21-91; analyzed: 6-27-91

34-21

Fig. 31 — Apparent viscosity vs. temperature. Specimen: W. D–H. Fluid: serum. RPM: 1.5. Data: 6–17–91; analyzed: 6–20–91

Fig. 32 — Apparent viscosity vs. temperature. Specimen: rabbit. Fluid: serum. Data: 6–21–91; analyzed: 6–26–91
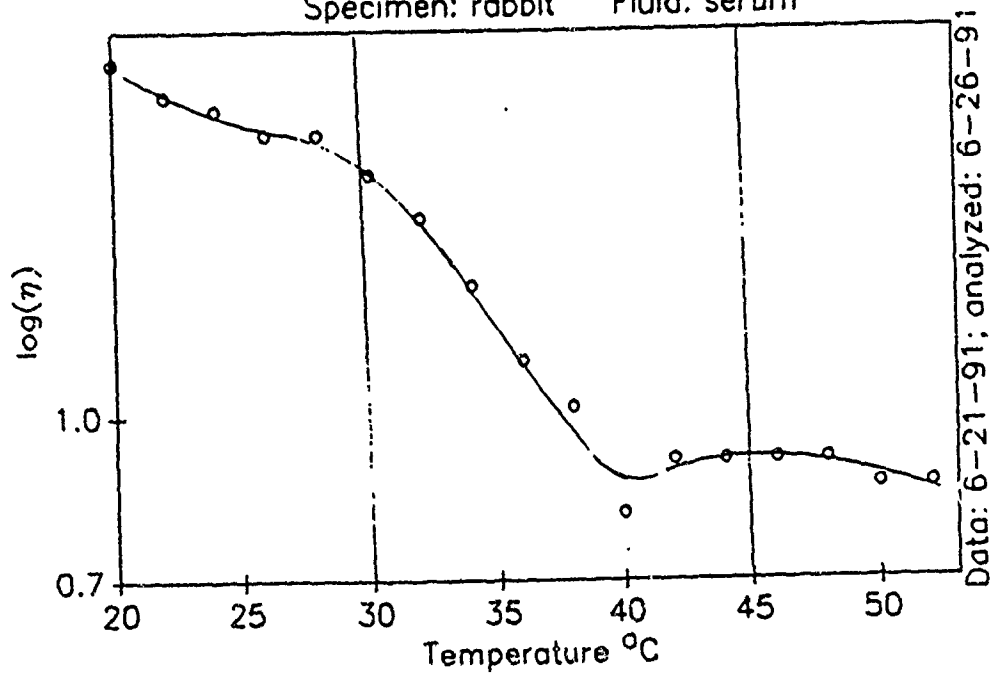
Figures 31 and 32 show typical viscosity data for blood serum. In these cases no dramatic increase occurs above 45°C. This suggest that the protein responsible for the increase in the viscosity of the plasma (and thus likely in part responsible for the reduction of the settling rate of the erythrocytes) is the fibrinogen which is removed in the clotting process. In separable measurements, we have confirmed that the viscosity of fibrinogen solutions (0.3%) increases dramatically above 45°C; Figures 33 and 34.

Note in Figure 27 - 34, that anomalies are sometimes seen at 30°C, and if not, at 45°C, and sometimes at both temperatures. The anomalies are of considerable interest as they occur right at the "Drost-Hansen thermal transition temperatures" (Drost-Hansen, 1977, 1987, 1979, 1991a, 1991b, Etzler and Drost-Hansen 1983. Clegg and Drost-Hansen 1991) suggesting a role for vicinal water: in this case the vicinal water of hydration of the plasma or serum proteins. In this connection we have also measured viscosities of some more well-defined aqueous polymers. Thus, Figures 35, 36. and 37 show, respectively, the results obtained on 5% polyvinyl pyrrolidone (MW 40 000 Dalton) and 5% dextran (MW 67 000 Dalton and 82 200 Dalton). In all cases thermal anomalies are seen at or near the vicinal water transition temperatures. Likewise, Figures 38 and 39 show the viscosity of 5% BSA; again the thermal anomalies are seen. Together with the other lines of evidence previously published, it now appears ALL polymers in aqueous solution are vicinally hydrated and that these vicinal hydration structures must be taken into account in all studies of such solutions, both in model systems and all living cells. Indeed these findings must ultimately be considered in all areas of cell physiology, biophysics and molecular biology.

CONCLUSION

In blood form all mammals tested (humans, chimpanzee, baboon, dog, cat horse, cow, goat, sheep, rabbit, pig, llama, and killer whale) the erythrocyte sedimentation rate in whole blood drops abruptly at temperatures above 45 (- 46)°C. In suspensions of erythrocytes in protein-free isotonic solution, the sed rate is much lower but also drops sharply above this critical

Fig. 33

Apparent viscosity vs. temperature
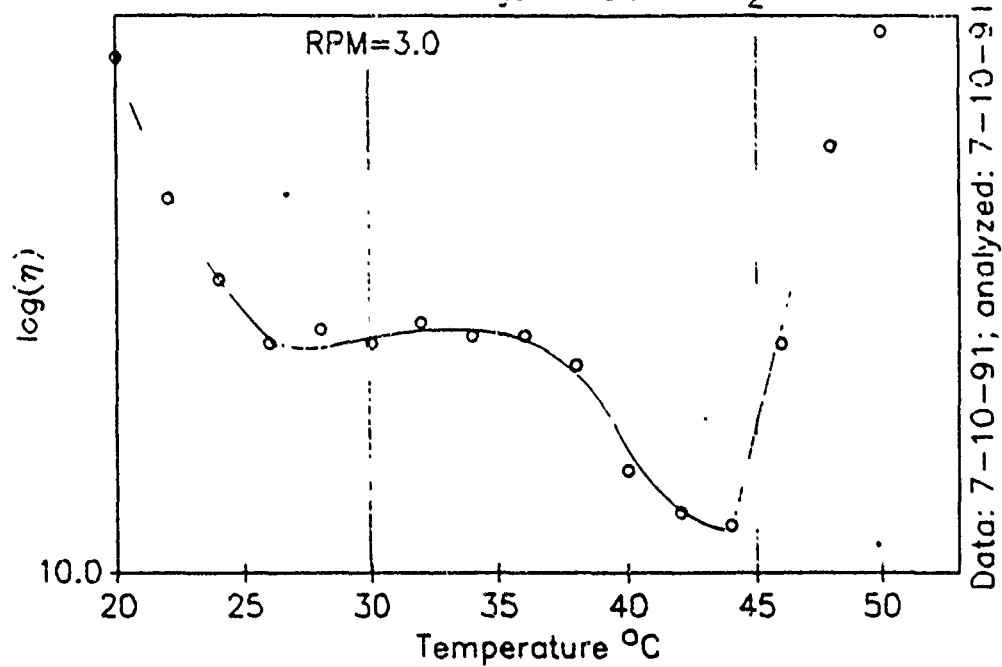0..3% Fibrinogen in distilled H_2O

Fig. 34

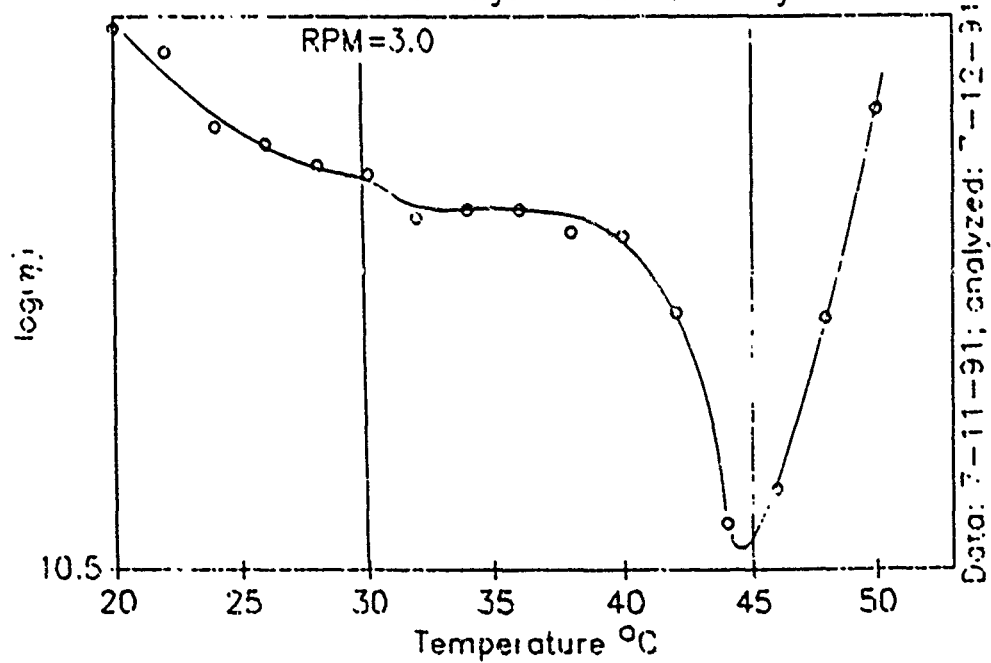Apparent viscosity vs. temperature
0.3% Fibrinogen in lactated Ringers

Fig. 35 — Apparent viscosity vs. temperature
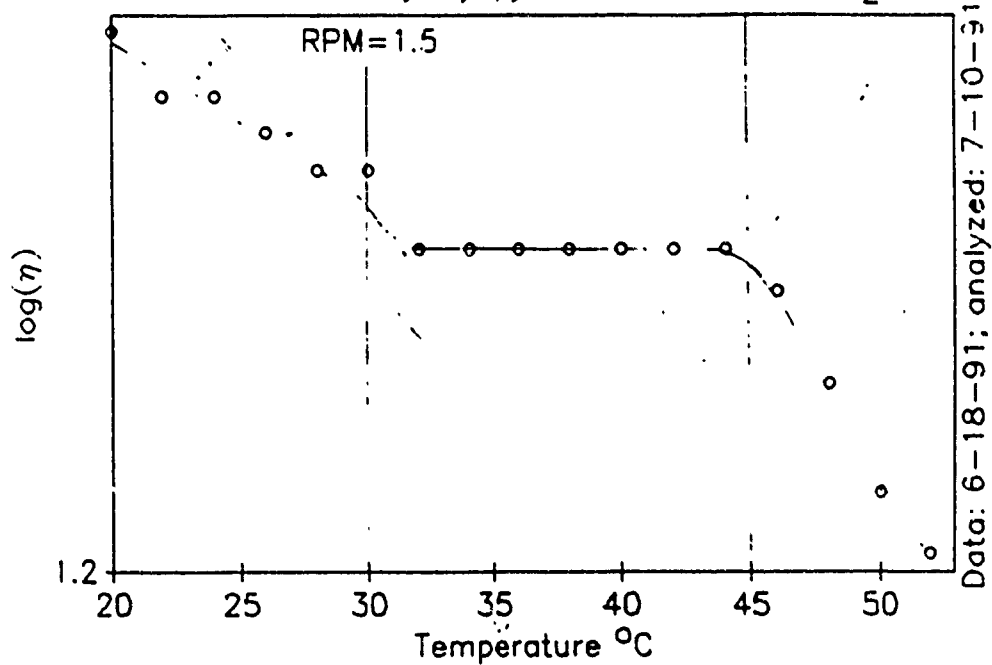5% Polyvinyl pyrrolidone in distilled H_2O

RPM=1.5

Data: 6-18-91; analyzed: 7-10-91

Fig. 36 — Apparent viscosity vs. temperature
5% dextran   MW: 67,000 D

RPM: 30.0

Data: 6-20-91; analyzed: 6-20-91
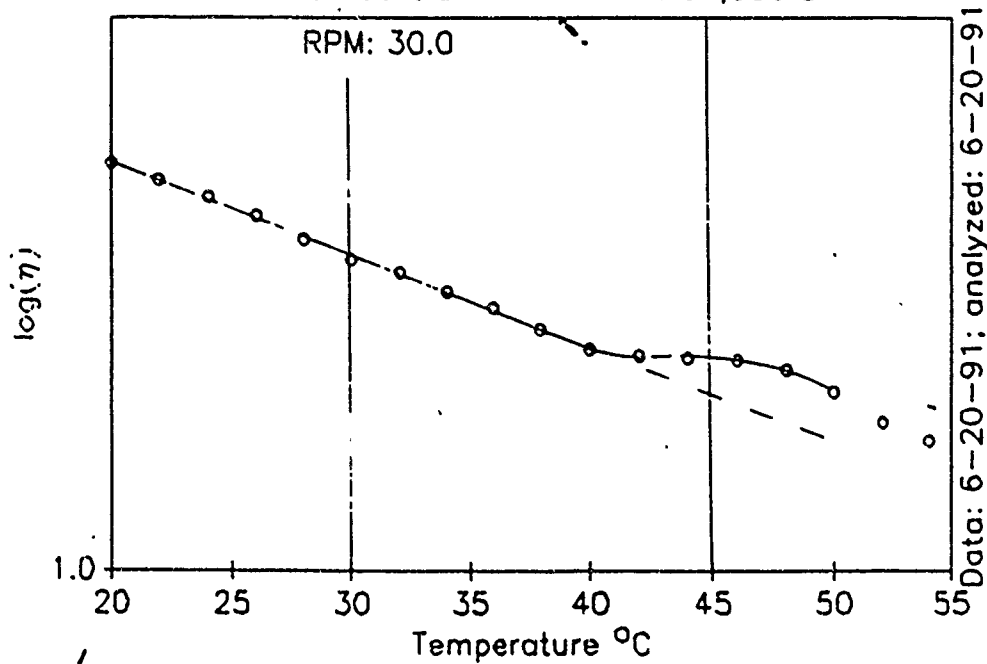
Fig. 37 — Apparent viscosity vs. temperature
5% Dextran   MW: 82,200 u
RPM = 12.0
Data: 7-15-91; analyzed: 7-15-91
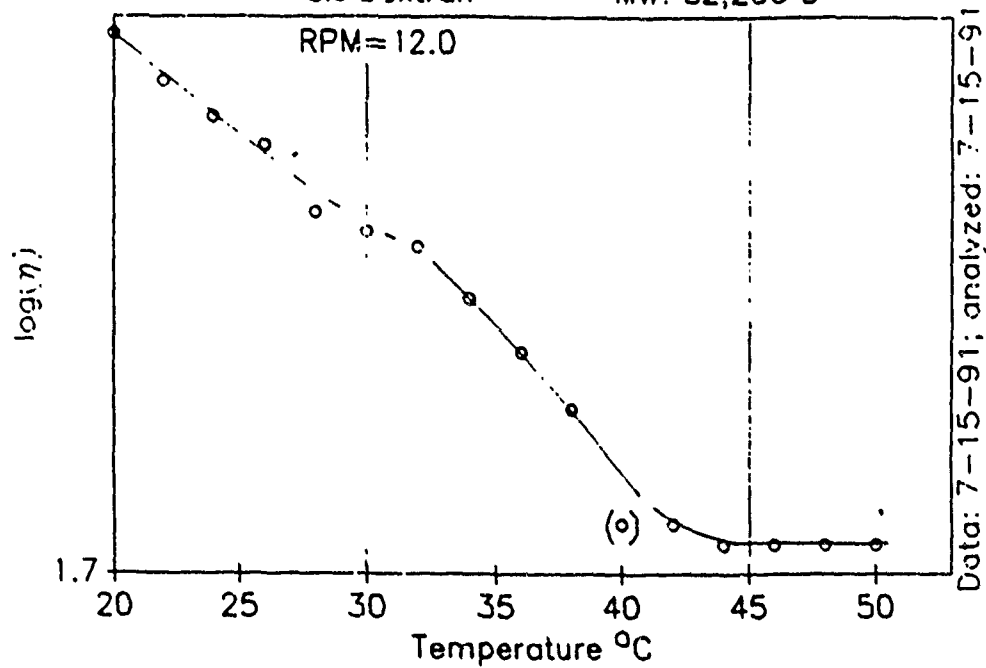
Fig. 38 — Apparent viscosity vs. temperature
5% BSA in doubly distilled H_2O
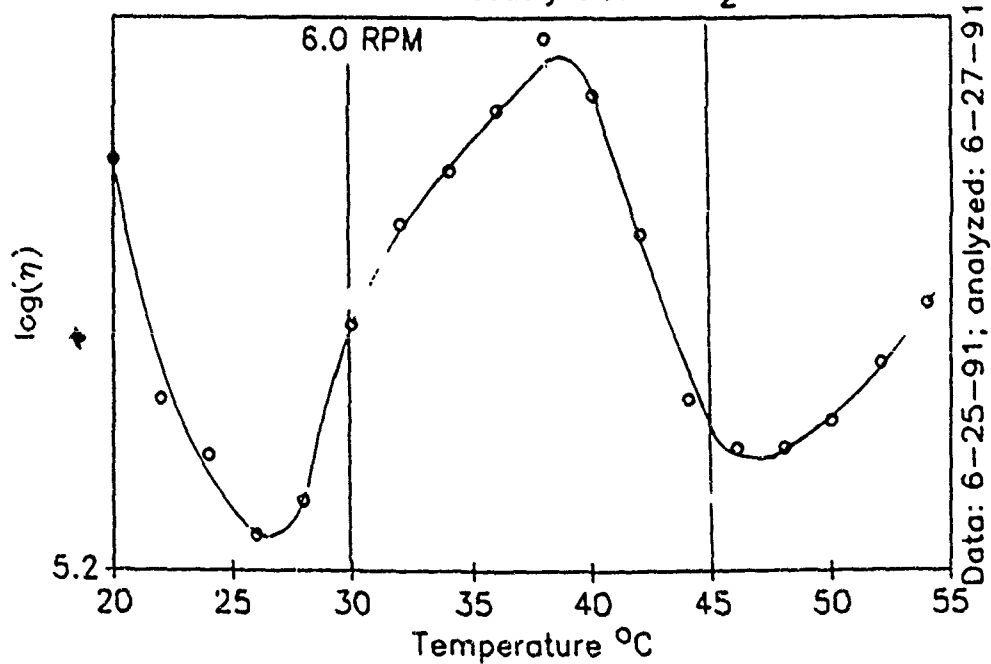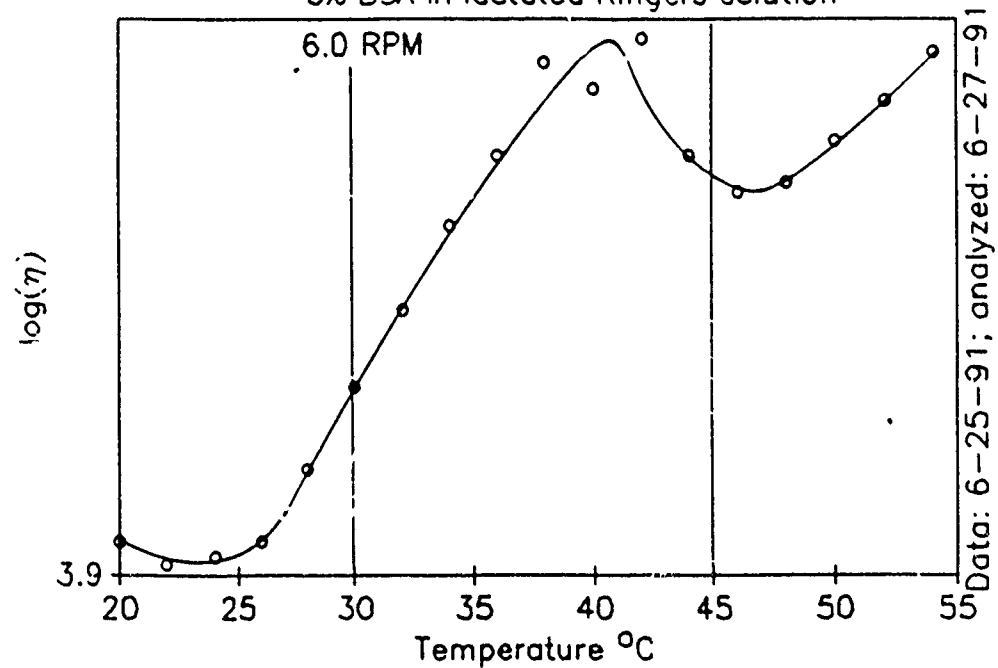6.0 RPM
Data: 6-25-91; analyzed: 6-27-91

Fig. 39 Apparent viscosity vs. temperature
5% BSA in lactated Ringers solution

temperature range. The latter observation suggests that some intrinsic property of the erythrocytes themselves senses that the temperature has passed one of the critical structural transition temperatures of vicinal water (which certainly includes the cell-associated water.) Furthermore, in whole blood, histological examinations have shown that erythrocytes undergo profound morphological changes near $45^{\circ}C$, changing from the normal biconcave disk form to more nearly spherical - thus preventing the rouleaux information which is critical for high sed rates. Other histological examinations have shown that above $45-47^{\circ}C$ there is a dramatic, almost grotesque, tendency for platelets to aggregate. Finally, we have shown that the viscosity of plasma increases dramatically above $45^{\circ}C$ which in turn must surely strongly reduce the sed rate. It is of interest to note also that no similar increase in viscosity with temperature is seen in the serum from blood of the identically same donors, suggesting that the abrupt viscosity increase in the whole blood plasma is due to fibrinogen. Consistent with this finding is our observation that the viscosity of aqueous fibrinogen solutions (0.3%) also increases abruptly above $45^{\circ}C$. Measurements have also been made on aqueous solutions of Bovine Serum Albumin, dextrans (2 different molecular weights) and polyvinyl pyrrolidone. All the solutions have shown distinct thermal anomalies near 30 and/or $45^{\circ}C$, strongly suggesting that ALL polymers in aqueous solutions are vicinally hydrated and displaying the characteristic thermal responses: i.e., structural transitions at one or more of the "Drost-Hansen thermal transition" temperatures, T_k,(namely, near 15, 30, 45, $60^{\circ}C$.) In short, the properties of blood is notably affected by - and some times completely controlled by - vicinal water, as are indeed practically ALL living systems (and all polymers in aqueous solution as well.)

W. Drost-Hansen

Miami, Florida

July 1991

FINAL NOTE:

A vast amount of data have been accumulated this summer (as well as in the summer of 1989) and it is our intent to publish these results in a series of four or five papers, variously co-authored with Drs. J.H. Cissik, W.R. Patterson, Mr. J.P. Lafferty, IV, and Mr. R.R. McNeer. I wish to express my sincerest thanks to Drs. Cissik and Patterson, as Director and Deputy Director, respectively, of the Clinical Investigation Directorate of Wilford Hall USAF Medical Center (Lackland AFB, San Antonio, TX) who have been instrumental in making this study possible, as well as the Summer Faculty Research Progɪ ɪn of the US Air Force Office of Scientific Research.

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1991 USAF-RDL SUMMER STUDENT RESEARCH PROGRAM

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FINAL REPORT

DIABETES, EXERCISE AND LIPID ABNORMALITIES:
SELECTION OF A POPULATION FOR STUDY

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DIABETES, EXERCISE AND LIPID ABNORMALITIES:
SELECTION OF A POPULATION FOR STUDY

ROBYN C. ROBINSON

ABSTRACT

Criteria for entrance into or exclusion from a study of aerobic
capacity and exercise effects on lipids of diabetes patients is
presented. Of 283 patients contacted by phone, 42 were accepted for
study toward a goal of 110 patients. Baseline lipid studies for these
patients is presented. Physicians recommend that their diabetes
patients exercise. However, the most effective way of obtaining
adherence with this recommendation is not known. The purpose of this
investigation is to evaluate different of approaches for encouraging
patients to consistently exercise and prevent complications of their
disease.

INTRODUCTION:

My purpose in this report is to examine the kinds of patients who
might or might not benefit from a exercise prescription. The benefit
to be examined centers on proposed favorable changes in lipid profiles
in type II diabetes mellitus. Inadequate levels of insulin or
resistance to insulin may lead to an increase in triglycerides,
chylomicrons, cholesterol and VLDL as is seen in many Type II diabetes
patients.[1]

Exercise increases one's sensitivity to insulin, thus it may also have a beneficial effect on lipid profiles of diabetes patients. Other benefits of exercise may be better circulation, lowered blood pressure, improved glycohemoglobin levels, enhanced self-esteem, and lowered stress. [a]

MATERIALS AND METHODS:

Since 1989, a registry of Diabetes Education graduates has been kept. The method of patient contact was by phone. If the patient met all initial screening criteria on the first call, they were invited to recruitment sessions on the second phone call. Foot status, cardiopulmonary history and self blood glucose monitoring were assessed at the recruitment sessions.

Exercise prescription: An individualized program of exercise was prescribed for each patient upon acceptance for the study. This prescription took into account the level of activity of each patient. Target heart rate, duration, frequency, intensity and rate of progression of exercise are all part of the prescription (see attached). Patients are given special instructions on avoiding the risks from exercise for patients with diabetes, such as hypoglycemia and foot injury.

Self blood glucose monitoring (SBGM): Patients bring in their SBGM logbooks at the initial visit and every visit thereafter. Blood glucose values are evaluated at each visit to determine whether the patient's diabetes is in good control.

The following lab tests were done upon entering the study:

Lipids and lipoproteins: Standard lipid profiles as part of standard of care were run on all patients. Thus, testing for HDL, LDL, VLDL, total cholesterol and triglycerides (TG) was accomplished. In some patients, whole fresh plasma is to be ultracentrifuged to obtain chylomicrons, chylomicron remnants, and very low density lipoprotein fractions in a supernatant. This fraction is to be separated and its content of chlyomicrons and very low density lipoproteins (VLDL) quantitated by high pressure liquid chromatography. The infranatant is to be separated by density gradient ultracentrifugation to quantitate the atherogenic intermediate (IDL) and low (LDL) density lipoproteins as well as Apo B-100 and Apo B-48. Protective HDL and apoprotein A-1 will be measured.

Glycosylated hemoglobin: This is a measure of the degree of hyperglycemia. Glucose irreversibly links to hemoglobin in proportion to the glucose content in the blood. Anticoagulated whole blood is collected and assayed fresh within 24 hours of sampling. Spectrophotometric methodology is used to measure the percent glycosylated hemoglobin separated by elution from a boron-agarose affinity column. This value determines how well controlled a patient has been in the past few months before enrolling in the study. A value less than 15 % permits a patient to enter into study.

Physiologic testing: A simplified, computer assisted measure of aerobic capacity has been developed by aerospace physiologists at Brooks Air Force Base School of Aerospace Medicine. A cycle ergometer was used to measure aerobic capacity based on a steady state heart rate. Basic features of this testing included:

1. Aerobic capacity is defined as the estimate of maximal oxygen uptake (estimated VO-2 max) derived by extrapolation from the relationship between steady state heart rate and power output. This is expressed in ml oxygen uptake/ (min x kg).

2. Target heart rates for making an estimate of aerobic capacity was kept in the range of 110-150 beats/minute at an initial 25 watts to 250 watts work load.

3. A pacing device (metronome) is used to help regulate pace of pedaling (50 rpm).

Bone density, percent body fat, urinary protein, and creatinine clearance were also measured. Dietary analysis is to be done by a dietitian. Clinical assessment of activity was accomplished whereupon patients were grouped in active versus inactive pools.

RESULTS:

Since 1989, approximately 600 diabetes patients have graduated from Diabetes Education Classes taught by Lois Wingate, R.N.,B.S.N., Certified Diabetes Educator at Wilford Hall Medical Center. This registry identifies name, date of birth, and phone number. Of these 600 patients, 283 have been contacted to date. Twenty-three patients

await scheduling for our next recruitment session. A total of 42 patients have been selected to enter into study as of September 17, 1991. Reasons for ineligibility for the other patients were as follows:

Pharmacotherapy: Because beta-blocker drugs and digitalis alter heart rate and obviate submaximal testing, 12 patients who were taking these agents were eliminated from this study but not from a general recommendation to exercise.

Uncontrolled diabetes: A glycohemoglobin value greater than 15.0 % or self blood glucose monitoring values greater than 250 mg/dL more than half of the time excluded patients from this study. Three patients were excluded from study until better glycemic control was achieved.

Age: As a result of the compound nature of multiple health problems (eg. crippling arthritis) as one ages, we arbitrarily excluded most persons born before 1926. Seventy-six persons were excluded from a second call to recruit for entry to study for these reasons (age and other illnesses. However, six were contacted and accepted.

Neuropathy/Nephropathy/Retinopathy:
Patients with severe peripheral nerve dysfunction, proteinuria greater than 1 gram or hemorrhagic retinopathy were excluded from this study. Three patients were excluded neuropathy.

Prior commitments: Seven patients were excluded because they were participating in a study of lipid metabolism and pharmacotherapeutics (AFCAPS) being run by the U.S. Air Force. Thirteen persons could not commit to this study because they could not take time off from work or school.

Lack of interest: Twenty-six people had no interest in participating in this study. Common reasons stated were ` I don't see how it would help me` or `I've already taken diabetes education classes`.

Miscellaneous: Eight persons could not participate because they could not find transportation or the hospital was too far from their homes. Two persons had unstable angina and arrhythmias. Two patients did not want to have blood drawn. One person was an amputee. One had a nonfunctional limb due to polio. Thirty-two patients were recruited for the intial screening visit, but did not show up. Twenty-two messages were not returned. Four patients came to the recruitment session, but were not interested in joining the study after hearing about it. Four persons were excluded because they were very intensive daily exercisers leaving little room for improvement, e.g. walk 10 miles per day. Three people were Type I diabetes patients.

Of the 42 diabetes patients who entered the study, 19 have were being treated for hypertension, 14 were being treated with gemfibrozil (Lopid), 6 were treated for both hypertension and hyperlipidemia.

Lipid profile data from 27 of the 42 patients was as follows:

	MEAN	RANGE	DESIRABLE LEVELS
LDL (mg/dL)	125	55-170	< 130
TG (mg/dL)	163	45-583	< 250
HDL (mg/dL)	38	24-82	(gender dependent)
Cholesterol (mg/dL)	198	149-271	< 200
Chol:HDL (ratio)	5.42	1.8-8.5	< 4.5

Mean glycohemoglobin (%) from 21 patients was 8.9 with a range of 5.6-13.8.

There were 13 female patients and 29 male patients. Mean age of these patients was 56. By clinical assessment, 19 patients were determined to lead an active lifestyle and 23 patients were sedentary.

DISCUSSION:

Of the 283 patients contacted, 42 were actually found to be suitable for this study based on exclusionary criteria. These criteria were chosen to protect the patient as well as contribute to the validity or ability to complete this study successfully. The mean age of patients was 56. There was selection bias in eliminating most persons over 65 in our preliminary screening because of the illnesses occuring in those over age 65, such as crippling arthritis. There were a greater number of male patients than female patients and this reflecting the sex ratio of middle-aged, retired military personnel. Conflicting responsibilities also skewed the mean age of participants upward as younger candidates had active duty work commitments, young children at home or were still in school.

Twenty percent of adults in the U.S. exercise adequately, 40% exercise below that needed for cardiovascular benefit, 40% are completely sedentary. [3] It is even more critical that diabetes patients exercise because they are at greater risk for poor health due to the effects of hyperglycemia on the peripheral nervous system, microvasculature of various organs and the eyes.

The burden of inactivity and lack of fitness on the diabetes patient is tremendous. The illness of diabetes costs the U.S. health care system approximately 20 billion dollars. Diabetes patients over 65 incur direct costs of 5 billion dollars. Complications of this disease have a particularly costly impact on various branches of health care services, namely, endocrinology, nephrology, ophthalmology, cardiology, and surgery. Diabetes is the fourth leading cause of blindness in the U.S. today. It is associated with a two-fold increase in incidence of myocardial infarction and an eight- to 150- fold increase incidence of gangrene. [4] The need for development of an effective exercise prescription which will motivate the diabetes patient to initiate and adhere to an exercise program is clearly evident.

The purpose of this study is to see what kind of effort is required to effectively enhance exercise behavior (i.e. increasing aerobic capacity). A secondary objective is to determine if positive benefits continue during 16 months of an effective program. In the design of this study patients taking Lopid were randomized to different groups

and matched so that similar numbers of patients were in the groups compared.

The Helsinski Heart Study demonstrated a 34% decrease in the incidence of coronary heart disease in patients treated with gemfibrozil (Lopid). [5] One of the questions posed by this study is to what extent exercise alone will reduce LDL cholesterol and elevate HDL cholesterol to desirable levels. The possibility that patients on lipid-lowering medicine (as well as oral hypoglycemic drugs) will be able to reduce or discontinue their medications is to be addressed.

As LDL is considered to play a major role in atherogenesis, patients with high LDL are to be targeted for lipid-lowering pharmacologic therapy. Low HDL or lipid-lowering pharmacologic therapy. Low HDL levels are considered a major risk for heart disease. Conversely, high HDL levels are cardioprotective. Type II diabetes mellitus patients may have low levels of HDL cholesterol [5] because of glycosylation of HDL which would enhance its clearance from the circulation. Improvement of these levels can be achieved by increased aerobic activity and changing dietary habits. Based on this solid framework of patient evaluation and selection, continued analysis may

be expected to yield information on the factors necessary to improve the lipid profile of the type II diabetes patient using exercise programs.

Type: Aerobic
Durations: 20 minutes minimum at TPR*; 60 minutes
                       maximum with 5 minute warm-ups and -downs.

Time: On arising/during workday/early evening
Frequency: 3-7 times per week
Intensity: Up to level of TPR (INDIVIDUALIZED--see table)
                       (60-85% of age-adjusted maximal heart rate)

Preparation: 5 minutes warm up by stretching
Termination: 5 minutes warm-down at 20-30% of training intensity
                       (i.e. maximal activity of exercise at the time)

Renewal: In consultation with physician, each four months

(Program to be reinitiated at TPR-1 if exercise activity has lapsed for 4-6
weeks)

*TPR   TRAINING PULSE RATE

AGE	TPR-1	TPR-2	TPR-3	TPR-4
UNDER 30	120	140	150	150-160
30-44	114	130	140	140-150
45-60	105	120	130	130-140
OVER 60	90	110	120	120-130
% of MAXIMAL HEART RATE	60-65	70-75	75-80	75-85
WEEKS AT TPR (Circled above)	_____	_____	_____	_____
GLYCOHEMOGLOBIN	_____ %	_____ %	_____ %	_____ %
Mo/Yr OF TEST	__/__	__/__	__/__	__/__

*Correlate with
Karvonen Formula: 200 - age = F
                    (F - Resting Heart Rate) x % of Max HR = P
                    P + RHR = TPR

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